ENGINEERING ECONOMICS BOOK II

Factory Organization and Management

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Factory Organization and Management

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PREFACE
TO THE SEVENTH EDITION

THE author of this book, Thomas Hall Burnham, died in London on 14th May, 1952, after the Sixth Edition was published It was his wish that the book should be kept in being through partial revision from time to time as republication became necessary and he entrusted this task to me

Engineering Economics was one of the first British textbooks on industrial administration the first edition being published in 1929

The purpose of the book was to help young engineers preparing for the professional examinations of the Institution of Mechanical Engineers which in 1924 included a question paper in Engineering Economics in these examinations The title of the examination was later altered to Industrial Administration but the title of the book, with its somewhat over-liberal use of the word "economics," remained

The examinations in Engineering Economics and Industrial Administration of the Institution of Mechanical Engineers, which have been taken by many thousands of engineers throughout the British Commonwealth, laid the foundation for the growth of education for management in the British Isles because all technical colleges had to embark on the teaching of industrial administration The necessity for the teaching and the examination has always been quite clear to mechanical engineers since it is estimated by the Institution that over ninety per cent of its corporate members hold managerial responsibilities of some kind

In submitting to this discipline, Burnham's book was the guide for most of us since it was a helpful attempt at organizing into a sensible sequence of ideas what we had to learn about the structure, working and control of an engineering enterprise

T H Burnham was himself one of the pioneers of teaching industrial administration in Britain While assistant to the managing director of a large steel company and later as a managing director himself, he acted as a visiting lecturer to the South East London Technical College In 1934, when I had the first chance of meeting him, he was using case-study methods of teaching which generated so much enthusiasm among his students that a live case study was started in the setting up of the "Case Development Co , Ltd " which is an active and flourishing company to-day

My purpose in the Seventh Edition has been to leave as much of Burnham's original writing as possible for new readers, for, like many others, I found his manner of writing stimulating I have done my best in a slight re-arrangement of the book which suits methods of teaching factory organization which have more recently been adopted Within the time at my disposal I have re-written and amplified some of the basic ideas about management and organization which will be found to be more in keeping with the suggestions of Lyndal Urwick than what has been printed in previous editions This is because I find that the Urwick theory of organization fits more closely than any other set of ideas I have come across, what actually takes place in a business—or what should happen for greatest effectiveness of management In making this revision it has been necessary to dispose of the "functional foreman" concept attributed to F W Taylor which is still put forward in all seriousness but which is now only of historical interest

D H BRAMLEY

January, 1957

PREFACE
TO THE FOURTH EDITION

THE basis of management action is scientific quantitative thinking, and one of the aims of this book is to direct attention to the necessity for criteria of industrial efficiency and optimum values It is not suggested, however, that in the last analysis management is a science No business, that is, no successful and progressive business, was ever run by charts and rules Successful management depends chiefly on the personal qualities of the manager, principally perhaps his flexibility, resilience, and perseverance As management is such a vital factor in industry, it is not surprising that it is increasingly appealing to the highly trained engineering student

Under modern industrial conditions, management has developed into a calling involving a special technique and necessitating a systematic scheme of education Since 1924, when the Institution of Mechanical Engineers introduced their study requirements, much has been done to develop the training of managerial ability The starting point is a knowledge of the technique of works organization, and it is this aspect of management which the present volume covers, viz the various factory activities, including design, equipment, operation, and cost control

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BOOK II

FACTORY ORGANIZATION AND MANAGEMENT

CHAPTER I

THE MANAGEMENT FUNCTION

IN Book I of ENGINEERING ECONOMICS we have seen how the modern industrial community arrived, how specialization of work under the "domestic system" led to a series of brilliant mechanical inventions which speeded output through the removal of some of the human drudgery in handwork methods, how increased skill in manipulating constructional materials led to the possibility of harnessing water power and later to the invention and successful application of prime movers, how the congregation of the machines round sources of power led to the "factory system" of organizing human work, how these advances were further stimulated by the rapid dissemination of knowledge and spread of ideas which resulted from improvements in communications, how the growth and improvement of transport led to a great expansion of trade, a rising standard of living in the industrial communities and an unparalleled expansion of world population

These vast changes have taken place within a span of little more than 150 years, it is little wonder, therefore, that social adjustment to the new living and working environments which have been created has been difficult and marred by human blunders, the greatest being two world wars which, in their turn, exaggerated the disparity between scientific and social progress by encouraging the one and impeding the other

INDUSTRIAL MANAGEMENT

We begin to realize that the simple alteration in methods of organizing work, from which all these changes have sprung, was not an "industrial revolution" from one static condition to another, now merely of historic interest, but a spark which liberated a "chain reaction" of dynamic change in human affairs Recognition of the dynamic nature of the environment of an industrial community is thus a fundamental assumption in all matters of human organization within such a community

The effectiveness with which work is organized decides the success of an industrial people and is no less subject to the need for this dynamic conception The changes in ownership, control and management of industry which have taken place since the beginning of the nineteenth century parallel the changes in other fields At the present time we are moving into an era when the social responsibilities of ownership and management of industry are becoming more widely and thoroughly understood, and when it becomes recognized that efficient application of the resources of production to available materials is not only a matter to be measured and controlled in relation to a satisfactory annual balance sheet but that community drives and social purposes are also involved

All who contribute to the agents of production in industry, those who finance new enterprises, or the expansion of existing ones, at attendant financial risk, those who accept responsibility in general or specialized fields of industrial management, those who apply their skill and labour to the productive processes and those who represent them, all have a common interest in the effectiveness of their labours through their duplicate roles as consumers But however great are the contributions of capital and labour—whether the capital be publicly or privately owned—the greatest responsibility rests with the industrial manager for it is through his understanding of his problem and the skill with which he handles it that the prosperity of the industrial community ultimately depends

DEVELOPMENT OF INDUSTRIAL MANAGEMENT

When we come to consider the historical background of industrial management, we find that the form of relationship between executive and worker with which we are concerned to-day is not much more than a hundred years old It has been indicated how the Industrial Revolution led to the growth of the workshop and development of the factory system Later on industry became organized into large groups and interests for the purpose of realizing the benefits of capital aggregations The growth of the joint-stock system has enabled management to be separated from ownership of industry, the latter only retaining the function of ultimate control, which in some cases becomes purely nominal Ownership is being spread on an ever-widening base and must operate more and more through management The burdens of responsibility have caused specialization in management, it is too much, for example, for one man to be expert in the functions of designing equipment, operating plant, purchasing, selling, accounting, and so on Management, therefore, should be shared by technical and non-technical men respectively, and not allotted solely to men trained in the commercial and financial branches of business, a practice far too frequently employed hitherto Technical men must, however, recognize the over-riding importance of the economic viewpoint in engineering and manufacturing processes Decisions in the management of any business must always be based on economic analysis, unless human or social questions are involved

Although scientific research on the practical application of technical principles to industry was commenced at Anderson's College as long ago as 1823, the so-called management movement is not half a century old Two of the most vital questions of industry are production and cost, and it should be noted that the management movement was initiated by engineers intent on solving problems of work output and cost and wage systems

THE WORK OF F W TAYLOR

Attention was first directed to scientific methods of increasing the effectiveness of manufacturing operations by

F W Taylor, who endeavoured to lay down definite principles and to elaborate the technique of management His work was taken up by others, such as Gantt, Emerson, and Gilbreth Before this work had proceeded very far it became clear that factories were not always correctly designed or arranged to obtain the greatest effectiveness of operation

The reasons for accentuated interest in management towards the end of the last century are not hard to find The average efficiency in large groups of industries was found to be very low, due to obsolete craft regulations and customs, unsuitable tools, haphazard engagement of workers, the absence of planning and reliance on rule-of-thumb, very simple changes in the arrangement and progress of work had the effect of considerably increasing output

As the size of plants increased, personal contact and the power of supervision lessened, so that other incentives to stimulate interest and effort were sought Increasing competition necessitated the accurate analysis of costs and enforced attention to systematic organization, co-ordination, and planning of production

F W Taylor laid the foundations of his important contribution to the science of management between 1880 and 1890 In 1882 he joined the Midvale Steel Company and set himself to answer the difficult question of what should constitute a day's work It was here he carried out the famous experiments on metal cutting, resulting in the development of high-speed steel In 1898 he entered the employment of the Bethlehem Steel Company, and at this period carried out his classical experiments on shovelling and pig-iron handling, and developed his wage-payment system He endeavoured to find out the best way of doing a job so as to eliminate waste of effort, time and material Taylor was not good at generalizations, but he laid down certain fundamentals which he held to be the true basis of shop management They may be summarized as follows each element of a man's work should be accurately and minutely studied, for each particular job the best workers should be selected and then carefully trained, the management and men must co-operate in the productive processes, departmentalization is not only important but essential

Taylorism, however, had many defects, and interest in it gradually waned. In the first place, teaching anyone to be efficient is not popular, but the efficiency men appointed under this system were sometimes particularly objectionable and ruthless Extravagant claims were made, and some of the industrialists first to adopt the system were too impatient for results It has the demerit of largely neglecting the human element in industry, and in this connection it may be mentioned that the Taylor wage-payment plan, with its tendency to over-drive, badly penalizes the slow worker, however conscientious he may be There may also be a tendency under Taylorism to give such close attention to details that the broader aspects and larger factors in industry are overlooked

Nevertheless, it must be freely admitted that Taylor was a true pioneer and did great work because he concentrated attention on the need to apply to management the same care and constructive ability which has characterized advancement in mechanical invention and the other sciences His work has been discussed almost to wearisome length, yet little that is fundamentally new has been added to it

It should not be forgotten that it was Taylor who emphasized the importance of the systematic use of experience in management He insisted on the separation of planning from executive work, recommending careful planning based on scientific analysis by a special department organized for that purpose He originated the functional type of organization in which each sub-manager or foreman was entirely responsible for a single line of effort The training of workers in the best possible methods was an essential part of his practice He also insisted that the only equitable system of wage payment must be based on the quantity or quality of work performed

SCIENTIFIC MANAGEMENT

Scientific management may be used in a narrow sense to relate to the organization of human effort in a factory, or in a wide sense to cover the whole sphere of business enterprise

Scientific management is an attempt to determine and apply the facts and laws that underlie efficiency, embracing the following in its analysis the best situation and construction of shops, the most effective character and arrangement of machines, tools, and materials, the most efficient productive processes, the best methods of selecting and training men and the nature and amount of work that ought to be performed by each, and the most suitable method of payment in the interests of the individual and of efficiency

Industrial management has to be considered, however, in relation to the ever-shifting struggle of practical affairs, and has to determine the most efficient combination of the various factors of production to be utilized in a going concern under given market conditions At the present time scientific management is taken to imply that, based on an accurate knowledge of the market and ascertained facts, an annual forecast of probable sales is made and production planned to meet this forecast Operations are then controlled and corrected, if necessary, at frequent intervals to meet the sales position as it develops The management mechanisms available for economic production may be summarized as follows market analysis, budgetary control, stock control, process and operation analysis, planning and scheduling, quality control, labour incentives and control, cost control, and maintenance control The complexity of modern business increasingly necessitates these specializations in functions The importance of forecasts as an aid to management cannot be overemphasized, not only of sales, but of production, costs, expenses, profit, and so on, and the more "scientific" the management the closer is the agreement between these forecasts and the facts

WHAT MANAGEMENT IS

A simple, and thus satisfactory, definition of the term manager is, *a person who is responsible, or accountable, for the work of others*

This idea brings many more people into the field of management than would have been conceded some years ago It enables us to consider, for example, the managerial role of the chief designer, the chief accountant, the foreman—and even of the chargehand—as well as that of higher management

In this sense we recognize that well over ninety per cent of the corporate members of the chartered engineering institutions must have managerial as well as technical responsibilities Thus acquisition of knowledge about industrial administration is an essential part of the training of the professional engineer

THE MAKING OF A MANAGER

The making of a manager, however, is not simply a matter of acquiring knowledge It involves several major considerations such as, suitable personal qualities, experience of the job to be managed, coaching under good managers, appropriate technical knowledge and finally, perhaps, a knowledge of managerial techniques

Most people seem to agree that the possession or acquisition of suitable personal qualities is the dominant factor in training managers The consideration of personal qualities is such a vague area of thought, however, interspersed as it is with so many near-synonymous terms, that few people would agree to a precise definition of what is meant by suitable personal qualities On the one hand long lists of desirable traits are submitted which quickly add to the total of impossible Others simplify their thinking by seeking for a single thing such as loyalty Midway between these positions perhaps is a consideration of certain indispensable things which are vital in a manager

A manager must clearly be above the average for the community in brains—in the speed and accuracy of receiving and dealing with ideas

He must be naturally a co-operative and positive person who sees the best in people rather than the worst, who is encouraging rather than discouraging, who can accept difficulty as a challenge calling for increase of endeavour rather than an excuse for inaction He must be the sort of person who will be acceptable to his subordinates, to his colleagues of equal status and to his own manager His standards of conduct must be somewhat better than the average because so much attention is focused on all his actions It is obvious that both physically and mentally, a manager must be able to withstand the pressures of events and be able to retain his optimism, positiveness and consideration for others when things go wrong

There are few people who would dare to suggest how such qualities might be acquired if they are absent in a person otherwise qualified to have managerial responsibility Usually it is a matter of selecting a person who displays social skills such as have been mentioned Some people suggest that social skill is a matter of experience Others think that a disciplined study of the normal differences in human abilities and personality is of help Yet another view is that the influence of a manager on his subordinate is one of the greatest factors in building or adjusting a managerial personality

In so far as the practice of management is a pattern of behaviour it must be accepted that it is learned more by imitation than by rational processes Thus it is that the well-run organizations and the effective managers in them inevitably breed the good managers of the future For this reason, too, coaching of the potential manager by experienced managers is probably the most important element in any scheme of management training, and, in selecting a person for a managerial position it will be important to have regard to the quality of the organizations in which he has worked and the managerial skill of the people under whom he has worked

Some consideration must be given to the amount of experience of the job to be managed which will be needed Here again there is no general principle to apply With the growth of management training schemes since World War II some have tended to assume that there is a managerial type of person who can manage anything This concept owes something, perhaps, to the theory of universality of the established civil servant or of the serving officer No doubt it is a rough judgment which will be appropriate for some situations where processes are relatively simple and where little skill is involved in the operative tasks But in engineering manufacture lack of contact through experience with the diversity of engineering processes would be a serious disqualification for management and is unlikely to be tolerated The British motor industry, for example, is almost wholly managed by those who have been apprenticed in the industry—and this is always likely to remain so

Experience of the job to be managed is necessary to establish standards of what is possible, to know how the work can be organized, to be able to demonstrate, or at least be involved in, any new methods which are to be introduced, to have an understanding of the human problems of those responsible for performance, sometimes this experience of the job is necessary simply to be acceptable to associates and subordinates but even in this narrow sense it may be vital

In many management jobs some technical knowledge is necessary While the technologist with other gifts and powers may naturally gravitate to management it is necessary to distinguish between the technical knowledge needed by the modern research and design engineer and that which is needed in management. The manager must be able to assess the potential value of new methods. He must know what questions to ask, when to call in an expert and which kind of expert can best help. The growing technological complexity of many industrial processes demands even more specialization in the training of technical staff but it also creates a need, as yet unfilled, for a more generalized technological training for those who are to give direction in the technological industries.

The making of a manager also involves a command of the body of knowledge of industrial administration which has been growing up in recent years. Such knowledge cannot however be the single qualification of the manager. Rather must it be considered as being in support of a person who has the personal qualities, the experience and the training which have so far been outlined.

The passing of examinations in industrial administration subjects or the holding of a professional qualification in management cannot testify to competence in management. None the less a substantial body of knowledge exists upon which a manager must draw for the successful discharge of his responsibilities.

The purpose of a study of industrial administration is to avoid repetition by successive managers of the mistakes inevitable under the empirical methods of learning by which until recently British managers have been trained. It is to provide the rapid dissemination of any new techniques which have been proved successful. Perhaps the most important result of establishing a body of knowledge of industrial administration is to provide those who participate in it with a means of evaluating their own experience by comparative methods, thereby realizing the alternative ways of achieving results of which they would otherwise be unaware.

There has been a much more rapid and freer development of the teaching of business and industrial administration in the United States of America than in Britain In the U S A Universities there are more students of administration than of any other faculty and it is said to be unlikely that a person will be entrusted with managerial responsibility unless he has participated in some approved course of instruction in industrial administration Many observers think that the responsiveness to change and to the possibilities of new methods which is a feature of the practice of management in the U S A is a natural consequence of the development of teaching in industrial administration since 1910 and the high quality of the persons attracted to the teaching work in that country

THE TECHNICAL AND THE HUMAN ASPECTS OF MANAGEMENT

The job of a manager involves dealing with problems which are either of a technical nature, that is, to do with things, or of a human kind, that is, to do with people The problems of management cannot, of course, be so strictly divided as being entirely of one or of the other kind generally problems are partly human and partly technical

So that we may examine the practical implications of this simple analysis let us consider some examples of each kind of problem Such questions as, what is the best method of making this product, why is this component costing more to make now than previously, what is the most suitable way of arranging the lay-out of machinery in this department, which will be the best source of supply for this material—all these are problems which are predominantly technical, or, to do with things On the other hand, such questions as, why is Joe persistently late, why has Joe fallen out with Bill, what kind of training does Joe need, how can we encourage Joe to work harder or to produce less scrap—all these are predominantly human problems

In dealing with the technical aspects of problems, the manager must try to avoid personalities interfering with the achievement of the best possible solution For example, in trying to establish the best lay-out of the machinery in a particular department, the manager will endeavour to avoid discussions about who decides where particular things are to go he may not succeed in avoiding such questions but clearly he will try to do so Similarly in deciding upon the best source of supply for a new item which is to be purchased, the manager concerned must occupy himself objectively with the criteria of good purchasing, namely, price, delivery and quality and neglect the personality of the sales representative of a possible supplier who is anxious to obtain an order He may find it difficult to do this but clearly he must try In other words, the manager must try to de-personalize the technical aspects of problems which arise

One of the principal ways of de-personalizing problems is to arrange for them to be handled by specialists whose job it is to deal in facts such as a plant lay-out engineer, a cost accountant, a process engineer, or a purchasing agent When work is broken down into specialist activities it becomes necessary to have ways of unifying the results This is the purpose of organization

Organization is the method by which we attempt to de-personalize the technical aspects of the managerial problem It is manifested in defining and planning the relationships of jobs and in planning and establishing procedures

It is now interesting and significant to turn to the human aspects of management, that is the methods by which the manager must go about trying to solve the problems which have to do with people rather than with things Experience tells us that when problems to do with Joe occur, the manager must go out on to the factory floor and talk to Joe to try to find out what he is wanting, thinking, and feeling, to try to put himself in Joe's place so that he can see how things appear to Joe Then when he has analysed the problem, diagnosed the source of difficulty the manager must attempt to influence Joe—by reason, by emotional appeal—by using all the skills of his own personality In other words the manager uses personal techniques in dealing with the human aspects of the managerial problem These personal techniques are based on experience in dealing with previous problems of a human kind and in the making of a manager There can be no substitute for such experience of the problems of man-management, but there is a growing interest in the possibility of speeding up the growth of this skill by a re-organization of the teaching of psychology and by the discussion of case problems in human relations

It is of special importance to notice, however, that the method of dealing with the human aspects of management problems is the antithesis of that which is appropriate in handling the technical problems This, it is submitted, is a basic observation about the nature of management which has many implications—not the least of which is that the disciplines of training which produce the technologist are an embarrassment in the humanist and that the manager has to learn to think and act in two very different ways Further, it is an essential discipline in the practice of management to diagnose the nature of each problem and to deal separately and distinctly with the part of it which is to do with things, for here the techniques of organization will apply, leaving the human aspects of the matter to be dealt with by personal techniques based on experience and knowledge of human relations

ORGANIZATION

We can now proceed to an examination of the nature of organization but with the important reservation just made that organization can have only a limited bearing on the solution of human problems

The primary idea in organization is that responsibility and authority are complementary and generally indivisible A person cannot be expected to be responsible for anything or any sphere of activity unless he has, or is given, the authority necessary to discharge such responsibility Similarly a person cannot be allowed to have authority unless he has the responsibility of accounting to some one else for the use of the power entrusted to him

POLICY FORMING AND EXECUTIVE ACTIVITY

In work of managerial responsibility there are two different kinds of activity First, thinking and deciding about the future—forecasting, planning and the determination of policy second, putting policies into effect, or getting things done Thus we might say that the board of directors decides company policy and employs managers to execute the policy, it is in this sense that the term "executive" is synonymous with the term "manager" But such a statement is not wholly true since a manager who is responsible to the board of directors will always have to think about policy matters in order to make recommendations which the board may ultimately sanction At each subordinate level of management, too, there will be some pre-occupation with policy though greater responsibility for getting things done. The greater the responsibility in management, the more will the manager be involved in thinking about policies and forward plans and the less will he be involved in the executive activity of getting things done The more junior the responsibilities in management the less will the manager be involved in policy matters and the more will he be involved in getting things done

The distinction between the policy forming and the executive aspects of managerial responsibility has some particularly important implications Firstly, some people are better at one kind of thinking than the other Others cannot be effective in both kinds of activity at the same time Policy-forming thinking is seldom done to a timetable Managers charged with responsibilities for framing policy must have the freedom in time to think about what is to happen next and not be over-burdened with executive matters Those charged with executive responsibilities cannot always be expected to be good at policy matters and may sometimes need the help of specialist and professional planners or consultants to help them to plan their way out of difficulties A well known industrial manager has said that leadership is deciding where you want to go and then getting people to follow you, this simple and true statement illustrates the important distinction between policy forming and executive action which we have just attempted to make

DELEGATION

A third major concept in organization is that the executive aspects of managerial responsibility involve the idea of delegation A manager gets results through other people thus he must learn to delegate responsibility and authority to subordinates Although an attractive idea, delegation is difficult to learn Indeed some able men have been only poor managers because they have never been able to practise delegation One of the difficulties is summed up in the observation that if you want something done properly you must do it yourself The manager must cultivate tolerance of the alternative ways in which a subordinate will deal with matters delegated to him Yet another difficulty for many managers is the restraint which must be exercised in interfering with subordinates while they are dealing with delegated matters It is important to observe that in delegation the manager does not divest himself of responsibility but shares it with his subordinate, there can be no evasion of responsibility because a matter has been delegated to a subordinate the manager accepts responsibility for all the actions of his subordinates, he is accountable to a higher authority for their actions On the other hand the manager divests himself of authority when he uses delegation He retains only the power to require reports on the progress of delegated matters, to inspect and reject results, to change the method of delegation or, ultimately, to remove a subordinate whose performance on delegated matters is inadequate

The process of delegation produces a geometric progression in the growth of responsibility or accountability, but only an arithmetic progression in the increase of power or authority Thus in a well run organization we may expect to find many people with responsibility but relatively little wielding of authority

CONTROL

A fourth fundamental idea in organization is that the process of delegation and exercise of control must be complementary No matter can be delegated to a subordinate without, at the same time, introducing the appropriate degree of control Control is exercised by agreeing upon a time or date for report on what has been delegated or for its completion—and following up to ensure that the timing is observed Control is exercised by periodic inspection, by commendation or criticism when the delegated work is completed Control is also established by agreeing and setting targets for performance, often in financial terms, and by comparing results with what was expected

WHEN TO DELEGATE

What matters should a manager delegate to subordinates? What things should he do himself? It is fairly clear that the rule must be to delegate all matters to which previous policy decisions may apply—that is, wherever some earlier thinking can be applied to a new matter all that is necessary is to remind a subordinate of what was done before and make him responsible for achieving similar results This procedure leaves the manager free to deal with the exceptions to which previous policy decisions cannot apply so appropriately and to work out and get agreement on the new policy that is required It also leaves him free to exercise control and to pick up other kinds of exceptions such as those cases where policy is not proving successful Thus may the precious policy-forming abilities of the manager be conserved and used to maximum effect But if this process is to be possible it is important to ensure that policy decisions are committed to writing to ensure clarity and consistency in their future applications

CREATION OF DEPARTMENTS

One of the primary functions of management is to establish the channels of organization by which delegation will take place This involves analysis of the functions of the manager into separate divisions or departments which will respond to specialization, where the demarcation of interests can be defined with tolerable accuracy, and which will match the talents of the persons who are available or who can be obtained to be responsible for each department The major divisions of the overall responsibility of governing a manufacturing organization can be readily demonstrated as in Fig 1

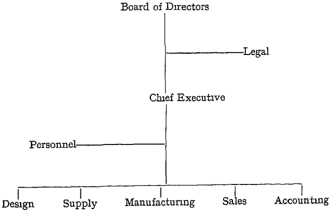

FIG 1 MAJOR DIVISIONS OF OVERALL RESPONSIBILITY IN A MANUFACTURING ORGANIZATION

Such divisions as these will not, however, be appropriate in every case As the pattern of delegation is broken down still further more consideration and greater analytical skill will be necessary In very small organizations it may not even be possible to achieve this first breakdown stage

Co-ordination or Unification

The next consideration in organization is the problem of unifying the activities of a number of subordinates to whom the manager has delegated responsibility and authority Continuous contact with subordinates is a vital prerequisite to effective unification—usually, daily contact This is to keep the channel of communication with subordinates freely open at all times so that minor and apparently insignificant matters may be discussed and commented upon as well as the major and vital issues Such frequency of contact is also to enable the thinking aloud to be done with boss and subordinates out of which natural collaboration may arise Another aspect of the problem of unification is the different ways in which the manager must team-up his subordinates in different matters of delegation and the fact that each subordinate is likely to enjoy a different quality of relationship with each of his colleagues, further that the qualities of these interpersonal relationships will vary, possibly from hour to hour The manager must be aware of these relationships, use those which are favourable whenever possible and take action to smooth out those which are difficult In order to obtain concerted effort towards the achievement of policies which have been prescribed it is essential that each subordinate should be aware of the actions being taken by his colleagues and of the policies under which the action is being taken Furthermore it is necessary to ensure accuracy in communicating the needs of each situation to those who must contribute to the satisfaction of those needs Such awareness and accuracy is only possible when consultative techniques are used by the manager frequent consultation between manager and subordinates is essential to effective unification

SPAN OF CONTROL

How many subordinate functions can a manager unify effectively? Should the answer be,

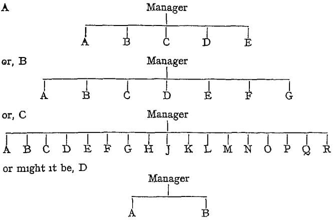

FIG 2 DELEGATION OF FUNCTIONS

The number of channels by which a manager delegates to subordinates is known as his *span of control* Some authorities have attempted to specify a particular number of subordinate functions for an effective span of control but it is suggested here that such theory is unlikely to be universal Let us examine this question by considering what is likely to happen in a system of delegation such as is illustrated at C in Fig 2 Without knowing the situation to which it applies we can be quite certain that if such an arrangement is used a number of operational faults will be inevitable such as—

1 Continuous contact between manager and each subordinate will not be possible The manager will be unaware of any but major events Most of his subordinates will only occasionally have contacts with the thinking and the policies of their chief

2 The number of different combinations of personalities which may be required to team-up to deal with delegated

matters is beyond the awareness of any manager No corrections of defective relationships will be possible the quality of action will suffer, some actions will be frustrated

3 When any one subordinate requires contact with his manager to obtain advice or decision some of his colleagues will be before him in a queue for attention Thus delay in decision-giving and dilatory response to events will be endemic

4 When the subordinate eventually obtains the time of his manager it is probable that others will now be waiting behind him in the queue for attention The manager will be under some pressure to deal with the matter as quickly as possible There may not be time to discuss all the relevant factors Snap judgments will be made There will be lack of quality in decision giving

5 When events cannot wait for the free time of the manager, subordinates will be forced to decide amongst themselves what is to be done The manager will lose control

6 There are so many channels by which exceptional matters may come up to the manager that he will be overburdened with executive work (getting things done) and have no freedom in time to think about the future or about policies which are to direct action Thus the organization will lack leadership

It is significant that these faults need not be because the manager is weak or inadequate, on the contrary he may be of great capacity, he will certainly be operating at considerable pressure The faults stem inevitably from a span of control which is too wide

Fixing the Span of Control

How then may we attempt to define the span of control which is likely to be effective for any particular position of managerial responsibility? We can approach this problem by considering the factors which influence the possibility of effective unification of command First there is the calibre of the manager himself, if he is a man of superior capacity he will be able to handle more subordinate functions It is natural however for some managers to feel adequate to control more subordinates than they are in fact able to do, thus there is a natural tendency for the span of control to be too great Second, there is the calibre of the subordinates If they are men of superior capacity they are less likely to pass on exceptional matters to their manager, thus allowing the span of control to be wider Here again it is sometimes easy to over-estimate the calibre of subordinates with a consequent tendency to allow the span of control to be too great Thirdly, however, there is the complexity of the subordinate activities and the degree to which exceptional matters are likely to arise If they are complex as, for example in jobbing production, then the span of control must be narrower, while in flow production systems, where careful planning is a vital pre-requisite to production, once production has commenced we can expect that the span of control might be wider

The only rule which will have general application involves the idea of restricting the span of control Thus we may lay down that—

The span of control of a manager must be restricted to the number of subordinate functions with which he can have continuous contact and which he can unify effectively

What if the span of control is too narrow? Here,

1 The manager will have too few channels to convey his thinking about policies into effect

2 His subordinates will not have time to work out the implications of one idea before the boss will be down with the next one

3 There will be over-inspection and over-involvement in details because the manager has nothing else to do

4 To avoid the bottlenecks provided by his subordinates there will be a natural tendency for the manager to lose patience and short circuit them by dealing directly with people lower down

Consideration of the span of control concept is perhaps the most important step in designing the organization structure of any concern or department within the concern The rules are simple and obvious to understand

Unfortunately we still come across able men in management whose activities are largely abortive because they have as many as twenty people answerable directly to them This may give a sense of power but it cannot lead to good management The effective span of control of a manager is much more likely to be five or six

DEFINITION OF RESPONSIBILITY AND AUTHORITY

We can now go back to the first principle of organization, namely, that responsibility and authority are complementary, and add to it the idea that responsibility and authority must be defined If there is failure to define and publish the responsibilities and the powers of each person in management, there can be no control by higher management of the pattern of the organization since each individual will be forced to build up his job himself, frequently out of conflict with his colleagues There will be evasion of responsibility when things go wrong and difficulty in preventing a recurrence by getting to the source of error There may be competition for the credit when things go well Definition of responsibility and authority is to avoid such weaknesses in the management of a business It is to enable each person to know to whom he must go to get a particular decision It is to make clear to everyone how the organization should work It is to create a feeling of stability, so that each person knows where he stands in relation to his colleagues Where such stability is not in existence it will be difficult for people to behave naturally with each other Status-seeking distortions of behaviour will occur

DEFINITION BY PRECEDENT

It is not always necessary to take elaborate measures to define the responsibility and authority of any job In stable organizations it is often clarified by precedent Thus we might proclaim that, as from a certain date, Brown will take over White's job, in the knowledge that everyone knows what White does The only care must be to ensure that everyone who has previously had to do with White is notified officially of the change

DEFINITIONS IN WRITING

Often, however, when personalities change in a business the opportunity is taken to make changes in organization When this is to happen it is vital to define the *changes* in responsibility and authority in writing and publish them to all persons who have in any way to do with the jobs in which the changes are to be made

Or, when a new managerial position is to be created, or when a new person is being brought in to take over an existing management job, it will be necessary to define the whole of the responsibilities and the authority involved

Although now a growing practice in British industry, there is still a good deal of reluctance to clarify responsibility and authority in this way One criticism usually offered is that an organization must be flexible and dynamic so that it can respond quickly to changes demanded of it and that meticulous definition of what is to be done by whom produces rigidity There is considerable force in this argument but it assumes that definition if it is to be done will be precise In practice such definitions merely summarize the nature of jobs with the accuracy which will give a predetermined degree of flexibility as may be decided by higher management Thus the terms of reference of the works engineer of a manufacturing concern need be no more than,

"The works engineer is accountable to the works manager He is responsible for the provision, maintenance and renewal of the company's buildings, all fixed services within the buildings and manufacturing plant He is also responsible for upkeep of the site and security and cleanliness of the premises The works engineer controls the clerk of works department,

the millwrights department, the plant overhaul department, the engineer's stores, the fire prevention department and the works police

The works engineer will authorize all expenditures in providing these services within an annual budget agreed with him or to special appropriations sanctioned by the Board and transmitted to him by the works manager "

Definition by Chart of Management Structure

It is often the practice to illustrate the organization of a business by publishing the management structure in the form of a chart, which demonstrates to whom each person in management is accountable This supports the written definitions of responsibility and authority, in some cases it is felt that such a chart gives sufficient definition without further elaboration The preparation of such a chart shows up any anomalies in organization, ensures proper economy in using managerial skill, illustrates the span of control of each managerial position and most important of all enables the ultimate principle of organization to be observed, namely, that each person shall have only one boss, or, no man can serve two masters A chart of management structure is valueless unless it is published and is public knowledge for all engaged in the business and all who have to do with the business It is also valueless unless it shows the names of the people responsible for each function Fig 3 illustrates the form such a chart might take to show the higher management structure of a manufacturing concern Figs 4 to 10 illustrate typical management structures for each of the main departments Figs 11 to 15 give the breakdown of the subordinate departments on the manufacturing side of the concern

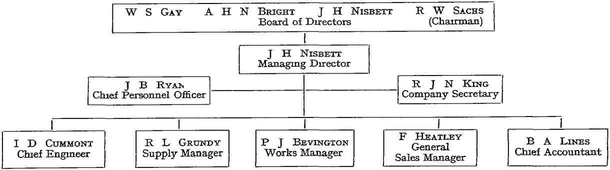

Fig 3 Example of Higher Management Structure in Manufacturing Concern

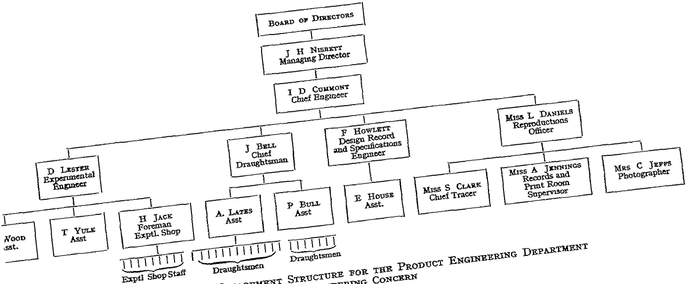
BOARD OF DIRECTORS
J H NISBETT Managing Director
I D CUMMONT Chief Engineer
D LESTER Experimental Engineer
J BELL Chief Draughtsman
F HOWLETT Design Record and Specifications Engineer
MISS L DANIELS Reproductions Officer
WOOD sst.
T YULE Asst
H JACK Foreman Exptl. Shop
A. LATES Asst
P BULL Asst
E HOUSE Asst.
MISS S CLARK Chief Tracer
MISS A JENNINGS Records and Print Room Supervisor
MRS C JEFFS Photographer
Exptl Shop Staff
Draughtsmen
Draughtsmen

FIG 4 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE PRODUCT ENGINEERING DEPARTMENT OF AN ENGINEERING CONCERN

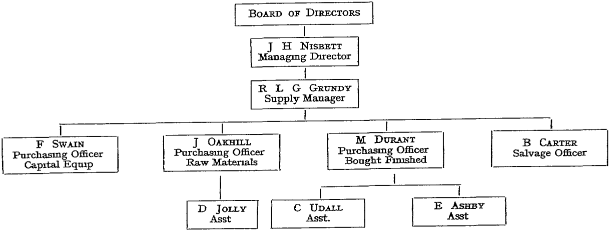
BOARD OF DIRECTORS
J H NISBETT Managing Director
R L G GRUNDY Supply Manager
F SWAIN Purchasing Officer Capital Equip
J OAKHILL Purchasing Officer Raw Materials
M DURANT Purchasing Officer Bought Finished
B CARTER Salvage Officer
D JOLLY Asst
C UDALL Asst.
E ASHBY Asst

FIG 5 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE SUPPLY DEPARTMENT OF AN ENGINEERING CONCERN

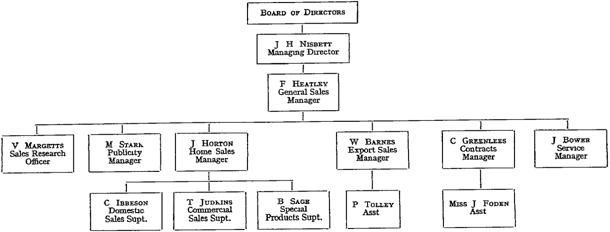
BOARD OF DIRECTORS
J H NISBETT Managing Director
F HEATLEY General Sales Manager
V MARGETTS Sales Research Officer
M STARK Publicity Manager
J HORTON Home Sales Manager
W BARNES Export Sales Manager
C GREENLEES Contracts Manager
J BOWER Service Manager
C IBBESON Domestic Sales Supt.
T JUDKINS Commercial Sales Supt.
B SAGE Special Products Supt.
P TOLLEY Asst
MISS J FODEN Asst

FIG 6 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE SALES DEPARTMENT OF AN ENGINEERING CONCERN

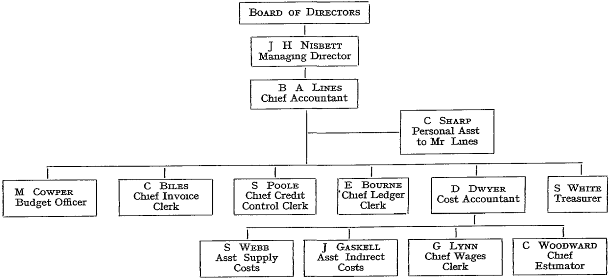
Board of Directors
J H Nisbett Managing Director
B A Lines Chief Accountant
C Sharp Personal Asst to Mr Lines
M Cowper Budget Officer
C Biles Chief Invoice Clerk
S Poole Chief Credit Control Clerk
E Bourne Chief Ledger Clerk
D Dwyer Cost Accountant
S White Treasurer
S Webb Asst Supply Costs
J Gaskell Asst Indirect Costs
G Lynn Chief Wages Clerk
C Woodward Chief Estimator

Fig 7 Example of Management Structure for the Accounting Department of an Engineering Concern

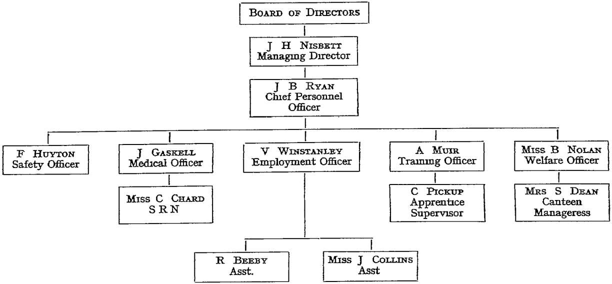

FIG 8 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE PERSONNEL DEPARTMENT OF AN ENGINEERING CONCERN

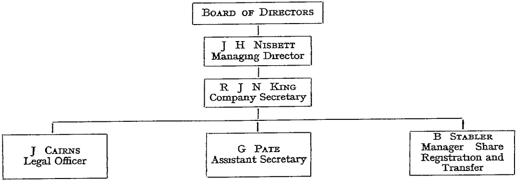

Fig 9 Example of Management Structure for the Legal Department of an Engineering Concern

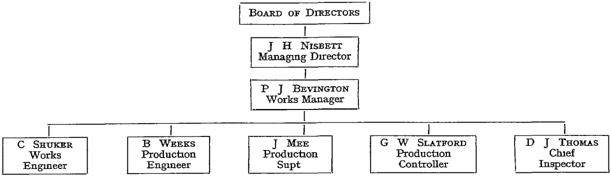

Fig 10 Example of Management Structure for the Manufacturing Departments of an Engineering Concern

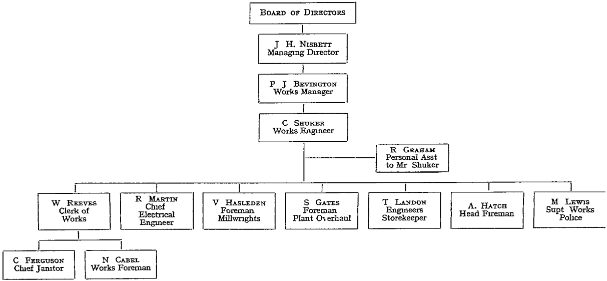

FIG 11 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE WORKS ENGINEERING DEPARTMENT OF AN ENGINEERING CONCERN

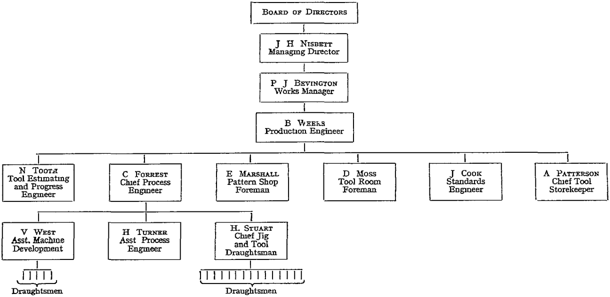
Board of Directors
J H Nisbett Managing Director
P J Bevington Works Manager
B Weeks Production Engineer
N Tooth Tool Estimating and Progress Engineer
C Forrest Chief Process Engineer
E Marshall Pattern Shop Foreman
D Moss Tool Room Foreman
J Cook Standards Engineer
A Patterson Chief Tool Storekeeper
V West Asst. Machine Development
H Turner Asst Process Engineer
H. Stuart Chief Jig and Tool Draughtsman
Draughtsmen
Draughtsmen

Fig 12 Example of Management Structure for the Production Engineering Department of an Engineering Concern

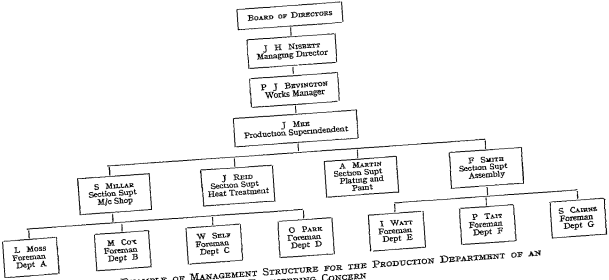
Board of Directors
J H Nisbett Managing Director
P J Bevington Works Manager
J Mee Production Superindendent
S Millar Section Supt M/c Shop
J Reid Section Supt Heat Treatment
A Martin Section Supt Plating and Paint
F Smith Section Supt Assembly
L Moss Foreman Dept A
M Cox Foreman Dept B
W Self Foreman Dept C
O Park Foreman Dept D
I Watt Foreman Dept E
P Tait Foreman Dept F
S Cairns Foreman Dept G

FIG 13 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE PRODUCTION DEPARTMENT OF AN ENGINEERING CONCERN

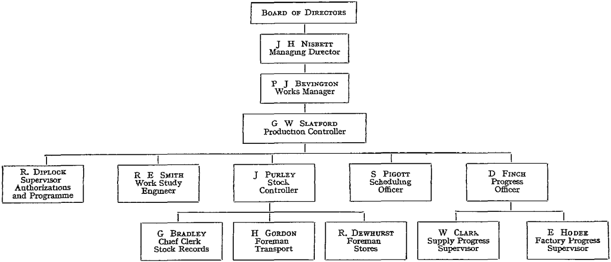

Fig 14 Example of Management Structure for the Production Control Department of an Engineering Concern

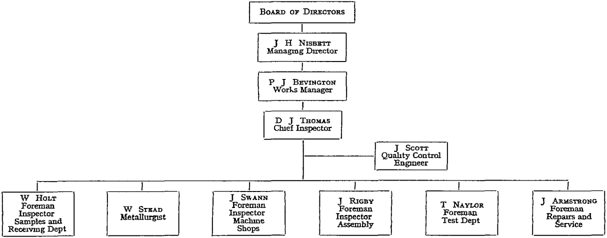

FIG 15 EXAMPLE OF MANAGEMENT STRUCTURE FOR THE INSPECTION DEPARTMENT OF AN ENGINEERING CONCERN

WHAT MANAGEMENT STRUCTURE DOES

Having established a management structure which applies to all areas of activity within a concern, we can now observe the ways in which it is used to facilitate the conduct of business. As we have just indicated it ensures that each person has only one boss, and who that person is. It defines the subordinate functions for which a manager is accountable to his own chief. It clarifies how the organization works and to whom one must go to get a decision on any particular matter. It indicates the status of each member of the organization. It demonstrates the channel by which policy decisions will be made known to each manager and through which direct instructions may be given. It shows who has power to appoint, promote, reprimand or remove from office at each level of management. It demonstrates the channel through which recommendations must be made and through which appeals may be registered against decisions thought to be unjust.

It controls the conduct of persons at each level of authority for a manager must not give instructions to those who are responsible to one of his subordinates, were he to do so he would damage the authority he has delegated to his subordinate. Similarly a subordinate may not go directly to the person who is over his own boss without the sanction of the latter, thereby he would short circuit the line of authority and display lack of loyalty.

LINE RELATIONSHIPS

The chart of management structure shows how authority has been delegated and to whom each person is responsible and defines what are known as "Line" relationships and what is sometimes referred to as the "Line of executive authority." The terms *Line responsibility* and *Line authority* may thus be applied to summarize the kind of responsibility and authority which are exercised through the lines of communication defined by the management structure. Line responsibility and line authority are the general management elements of any managerial function and cover all activities included in that function

ANOTHER KIND OF RELATIONSHIP

Having examined the kind of business which is transacted through the line relationships it is necessary to consider some other day to day activities which are not regulated by the line relationships—except in emergency Fig 16 illustrates the line relationships which may connect the activities of a workman in a production department and the inspector who verifies that the work done is satisfactory First the responsibility and authority in each job may be stated, the responsibility of the workman, Jones, is to produce the work to the time-cost and quality standards prescribed, he may be entitled to require that the material is correct and available before he starts, that any tools and instructions are also ready, that a piece work price or time allowance has been prescribed for the job and that his machine is in full working order The department inspector, Smith, has the responsibility of ensuring that the work produced by Jones is to the quality standards specified, probably, by the design department on the drawing of the component which is being made, the inspector's authority may be to require the workmen to submit a sample before he commences a production run, to require that any defective parts shall be corrected, to recommend that those which cannot be corrected be scrapped and authorize the wages department to pay piece work or premium bonus earnings for the good work that he passes How does the inspector exercise this authority? Examine one of his actions by supposing that out of 100 pieces made by the workman 5 require correction and 2 are to be scrapped If the line relationships were to be used it would be necessary for the inspector to submit a report to his chargehand who would pass it on to his foreman, then to the chief inspector who would have to ask the works manager to instruct the production superintendent to instruct the foreman to

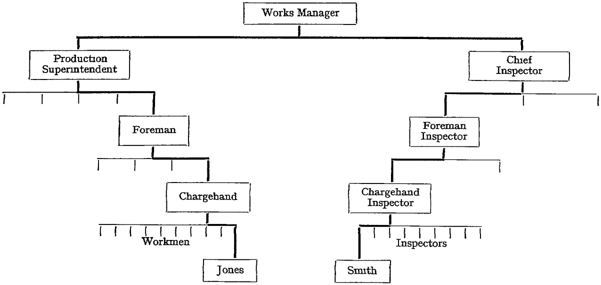

FIG 16 LINE RELATIONSHIP CONNECTING ACTIVITIES OF WORKMAN AND INSPECTOR

instruct the chargehand to instruct the workman to correct the five defective components, and tell him that two are to be scrapped Such a procedure is clearly ridiculous It is an understood thing that Inspector Smith has the power to tell workman Jones the result of his inspection and require him to correct the defective work Or, let us examine another case by assuming that a safety officer who is responsible to the personnel manager patrols the works and finds that workman Jones is operating his machine without the safety guard in place The responsibility of the safety officer might be to ensure that everyone in the organization works to the statutory requirements of the Factories Acts and the Orders in Council which apply to the industry concerned, that safe practices are used There must clearly be some complementary authority if the safety officer is to be able to accept such responsibilities He is usually empowered to stop work which in his opinion is unsafe, but how does he exert this authority? It would be ridiculous if it were necessary for him to get action through the line relationships by asking his chief the personnel manager to get the managing director to instruct the works manager to pass an order down the line of authority in his department for the job to be stopped until workman Jones has fitted the safety guard on his machine In many factories it is an understood thing that the safety officer is empowered to instruct the workman to stop the job if it is unsafe, or he may tell the chargehand or the foreman to do so

FUNCTIONAL RELATIONSHIPS

The case of the inspector and the case of the safety officer are by no means isolated examples of the responsibility and the authority which are not exerted through the line relationships but short-circuit these relationships Thus there is a necessity to recognize an entirely different kind of relationship which we may term "functional" and from which we may derive the terms *functional responsibility* and *functional authority* Examination will reveal that many, if not most, of the day to day actions which take place in an industrial organization are regulated through functional relationships, and not through the line relationships In some organizations the line relationships have never been clarified, the whole of the business being done through the functional relationships

The way in which functional relationships cut across the line of authority causes it to be specially important that the functional responsibility and the functional authority attaching to any particular job shall be clearly understood by all who are affected by it , thus special emphasis must be laid on the necessity to define functional relationships in writing , this is especially the case when a new functional relationship is being established, as, for example, when a safety officer is being appointed for the first time in a particular organization It is also essential that those entrusted with functional authority exercise it with care and consideration Some managers insist on deeming functional authority to be "advisory " It may be that the true position is somewhere between the words "instruct" and "advise " It is equally true, however, that if a person is made responsible for ensuring a specified result he must have the appropriate powers to control achievement

THE PURPOSE OF PROCEDURES

It is important to observe that most of the functional relationships in an industrial organization are covered by the procedural aspects of organization (see page 14), and that procedure has the value of de-personalizing functional authority Thus the functional authority of an inspector might be carried by a Reject Note, a Scrap Work Note and a Work Completed Note—or similarly titled documents The functional authority of a safety officer might be de-personalized by means of a "Stop-Unsafe-Job Ticket," though we know of no case where such a procedure has been found to be necessary The foreman expresses his functional authority to require stores to be issued to his department by authorizing a requisition on stores The chief draughtsman authorizes changes in design of work-in-progress by issuing a Drawing Office Alteration Sheet None of these functional relationships excite resentment when they form the understood way of doing business

WHEN FUNCTIONAL RELATIONSHIPS BREAK DOWN

What must happen, however, if functional authority is resented and opposed? If we go back to the example of workman Jones and Inspector Smith in Fig 16, we can assume that Jones refuses to accept the stand taken by Smith In this circumstance the inspector must report the matter to his chargehand who will attempt to renew the broken functional relationship by taking it to his opposite number who is in charge of Jones If they cannot agree it will have to be dealt with by the foreman and, if still no agreement at this level, to the chief inspector who may finally have to appeal to the works manager, this official must now sit in judgment and decide whether or not the work is to be corrected and his position in the line of authority enables this judgment to be made and an appropriate instruction given to either the production superintendent or the chief inspector Here then we have the final justification for defining and publishing the line relationships within an industrial organization by means of a chart of management structure for if there is failure to do this, breakdown in functional relationships will be difficult, if not impossible, to rectify

F W TAYLOR'S FUNCTIONAL ORGANIZATION

The conception of functional relationships which we have attempted to describe and illustrate in the foregoing pages is the natural development from the experiment in functional organization which was conducted by Frank Winslow Taylor the pioneer of scientific management in the United States of America Taylor's idea is illustrated in Fig 17

Such methods of organization were tried out in Britain in the early days of the growth of industrial concerns It is clear that such a system offends against the principle of unity of command where each person has only one boss and will always fail on this weakness alone It is also clear, however, that Taylor's concept of functional relationships was fundamentally correct for such relationships are taken for granted in every industrial organization to-day

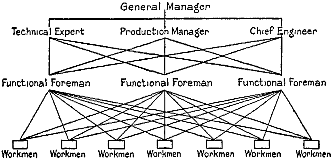

FIG 17 F W TAYLOR'S CONCEPT OF FUNCTIONAL ORGANIZATION

STAFF RELATIONSHIPS

A third kind of relationship in industrial organization is known as a "staff relationship" This occurs when a manager has attached to him an assistant who stands aside from the line of authority as in Fig 18

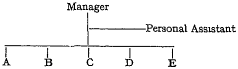

FIG 18

The purpose of this arrangement is generally to relieve the manager of routine, to enable him to conduct investigations and project schemes during a period of development without calling on his immediate subordinates In some circumstances it may be a way of relieving the faults of too wide a span of control It may, as has been suggested by Lyndal Urwick, be a way of providing a position in which younger men may go through a process of executive development prior to appointment to one of the subordinate positions in the line of authority A further suggestion has been made by Urwick that unification of activity might be achieved by a process of consultation between the personal assistants of each of the managers in an organization Success of the staff relationships rests on the idea that the person concerned is known as "Assistant to the Manager" or, preferably, "Personal Assistant to ——" and never as "Assistant Manager" If the person is interposed in the line of authority he should be styled "Deputy Manager", these arrangements are to clarify his position and thus avoid the misunderstandings and conflict which will otherwise arise An assistant who stands in a staff relationship to a manager cannot give instructions to the manager's line subordinates, he may seek information from them, he will often seek their help, he may communicate the decisions of the manager to them but not as coming from himself, usually he must deal with his manager's line subordinates as if they were senior in status to himself

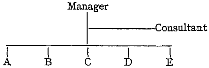

FIG 19

The staff relationship is also used when outside advisers are brought in to assist an organization, possibly by the introduction of new procedures or techniques (Fig 19) Here the consultant, although possibly a person of superior capacity and experience to the manager, must act as an adviser, all instructions resulting from such advice being issued by the manager

Thus we must observe that while in a staff relationship there will be *staff responsibility* there is no such thing as *staff authority*, at least in the formal and organizational sense in which we have been examining management relationships in this chapter Here, however, we touch upon the real nature of authority, as distinct from that which is conferred on or delegated to a person, for an understanding of which the reader is recommended to the collected papers of Mary Parker Follett which have been made available under the title, *Dynamic Administration*, edited by Urwick and Metcalfe

COMPLEX OF RELATIONSHIPS

Thus may we distinguish between "Line," "Functional" and "Staff" relationships in industrial organization The three different relationships are not always in evidence separately and in isolation Reference to Fig 20 will reveal that the personnel manager is shown in a staff relationship to the remainder of the organization, this is not a standard arrangement but recognizes the way in which most personnel managers conceive their role in the organization, namely, as being advisory to all departments on personnel matters Yet within the personnel department itself there may be a hierarchy of line relationships, depending on the size of the concern, and some of the line subordinates of the personnel manager may be vested with functional responsibility and authority While the establishment of a structure of management or executive authority and responsibility may be carried out under the advice of specialists, or by taking into account some of the considerations we discuss in this chapter, the implementation of any such scheme and its subsequent control is clearly a policy matter which comes within the administrative responsibilities of the directors of the company, and an essential rule to be observed is that no modifications can be made

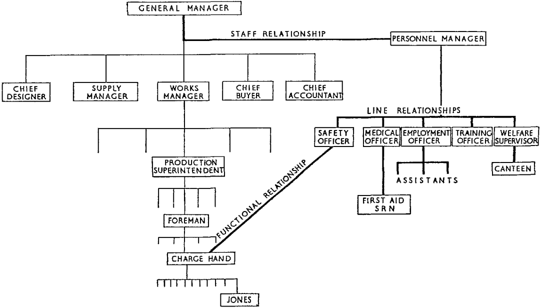

FIG 20 EXAMPLES OF LINE, FUNCTIONAL AND STAFF RELATIONSHIPS AFFECTING A PERSONNEL DEPARTMENT

to its provisions without approval of the board By this means the directors control the executive arrangements they employ for carrying their operating policies into effect The success of many undertakings can be attributed almost directly to the care and understanding of the problems involved that has been contributed to the design and establishment of a clearly understood chain of authority and pattern of co-operation to which each person with executive responsibilities must conform Failure to take this organizational step does not always, of course, lead to immediate deterioration of a business, but it certainly creates conditions whereby departmental individualism distorts management policies or stultifies them altogether, causes it to be difficult, if not impossible, for the business to react to changes in external conditions, and usually results in very low standards of management practice through the unwillingness of the more capable type of executive to operate in a system of undefined responsibilities and authorities It is probably because these deleterious effects are usually only long range in their effect that some undertakings have so far failed to take the corrective action which is open to them

The organization of an industrial concern is not, however, simply a matter of establishing an appropriate pattern of authority and responsibility for the executive personnel involved Consideration must also be given to economy of executive action and to the provision of information upon which executive policies may be planned Here organizational method is concerned with the clerical and technical procedures by which the day-to-day work of the concern is carried out, its objective being to establish a web of inter-related action which will be quite automatic in operation and which is affected as little as possible by the human factor In this context, and possibly only in this, we may permit ourselves to visualize the industrial unit as a complete machine which is operated by those carrying the administrative responsibilities, which is fed with raw materials on the one hand and with instructions as to what to make on the other, which has a productive system controlled automatically by a clerical and technical procedure which respectively feed in the raw materials and instructions supplied, which has a staff of managers who lubricate those working parts likely to get hot, replace those which fail or wear out, or patch up as circumstances dictate, and who otherwise deal with all those exceptional things which go wrong or require adjustment and which are not part of the routine of actually performing the productive work of the machine Unless the clerical and technical procedures operate quite automatically in the sense implied by this analogy, an increased load is placed upon those carrying management or executive responsibilities to the detriment of the time and attention they can devote to management action, for successful management largely depends upon ability to get things done either by delegation or by committing routine matters to a carefully designed procedure and upon deciding which matters cannot safely be delegated or submitted to routine and which thus require personal attention

It will be observed that the two kinds of organizational method we have discussed, namely the establishment of a system of human relationships on the one hand, and the creation of an automatic clerical and technical procedure on the other, both have the objective of eliminating from the conduct of the concern those human factors which are detrimental to it, or of eliminating the human factor, as far as is possible, wherever it is inappropriate It is clear, of course, that such objectives can never be reached in practice however much we may disagree with those who consider that individualism in all things is preferable to organization In other words, we have to reckon with the fact that human difficulties and problems will constantly arise in the day-to-day management of a business, that individualism will require correction and that too modest forms of enterprise will require encouragement Here are problems which no organizational system or procedure can handle These are human problems arising from human personalities They require personal forms of solution and clearly, the form of the solution must always be personal action by management

WHAT IS GOOD ORGANIZATION?

Can good organization be defined? Perhaps not in so many words, but it is not difficult to say what it does, and judge it from the results produced The vital importance of the subject is indicated by the references to firms which have not done well being in process of reorganization Organization is something more than subdivision Subdivision of labour is good, for it tends to increase output and improve quality, but it only yields increasing returns up to a point, and careful judgment must be exercised in determining how far specialization is to be carried

Organization is something more than system Systems are of the utmost utility, but will not work themselves Methods will not run a business The directors have to run it and the staff has to be built up into a team imbued with co-operation in which initiative and elasticity are preserved We must guard against overvaluing organization and undervaluing personality The fundamental of control is to demand results and leave the subordinate to achieve them as he thinks best Elasticity and initiative must be preserved, for it is almost impossible to foresee everything that ought to be done To give too detailed instructions kills initiative, as the subordinate can say that obviously this or that ought to have been done, but it was not in the orders given Devolution encourages decision and self-reliance Impulses for action must well up from below Good organization facilitates control of production and enables the work to be fitted into the departments and progress smoothly through the plant without congestion or delay or friction between the staff

In the factory, organization increases the productive capacity of the plant by ensuring continuity of process and elimination of idle time The work passes through the stages of production with no unnecessary handling Organization results in smaller amounts of work in progress and a smaller stock of raw materials, and gives a greater security in fulfilling orders It should be remembered that it is detrimental to goodwill to have to wait beyond the promised delivery Good organization increases the output of saleable goods, decreases the costs of production and distribution, and makes economical mass production possible, in other words, organization enables the executive to obtain the utmost value from the investment in buildings, plant, and tools It is capable of accommodating itself to unexpected demands, such as an urgent request for speeding up in special cases, i e it does not break down under stress

A good organization is not impaired by the absence of particular individuals If the return of an official has to be awaited before certain work can be started or resumed, the organization is defective In a well-organized works there is no hesitation in carrying on in the absence of individual members of the staff, as it will have been laid down who will deputize in such an eventuality This opens up the important question of training men for future direction There is a well-understood, because very human, disposition or rather temptation for officials to withhold a greater or less proportion of the functioning of their position from their assistants It is not too much to say they definitely hope that in their absence trouble and difficulty will be encountered, and their value to the enterprise then be more highly estimated However, the highly placed executive who said he was going for a holiday because the concern got on as well without him as with him was without doubt a true organizer His statement was not quite correct, because there were matters on which only he could give a decision, but they were such that he could do this just as well on a golf course as seated at a desk If every one in the firm had not known his job and the questions which had to be referred to the executive for his yea or nay had not been clearly defined, the latter would have had to be in his office grappling with questions which a subordinate could have dealt with An enterprise does not run itself, but a well-organized one almost seems to do so

The basic principle of organization is co-operation It facilitates executive control, and the achievement of policies

In addition to the use of charts, control is aided by records and reports, but a paper-work system must not be carried too far For example, standard procedure instructions have their place in both shop and office routine, but the acid test of organization comes in dealing with matters for which there is no precedent

The fundamentals of organization, then, consist in the provision for the automatic initiation of action, the establishment of appropriate rules and regulations relating to production, the automatic supply of reports from subordinates, and the development of an adequate system to eliminate waste of time and effort Everyone in the works should know his relative duties and handle routine matters without direction from above

It must be remembered that any process of organization is deliberately making grooves, and, therefore, the grooves must not be cast-iron ones, but capable of being improved by methods which experience elsewhere has proved to be successful

Attention given to organization really represents recognition by the management of the necessity for exploiting the resources of the factory to the fullest extent with a view to getting the utmost return for their expenditure

When reorganization is necessary it usually requires a bold policy for satisfactory results, as changes are opposed by foremen, heads of departments, and others affected, but the issue of the economic functioning of the plant as a whole is too great to allow individual opinions or preferences to interfere

In all matters concerning organization the co-operation of the accountant is necessary, as he will criticize any changes from the cost accounting point of view The financial aspect of the enterprise is of overriding importance

Organization to-day is not only a power but a necessity The more closely knit an industrial unit is, the greater its efficiency and competitive strength

THE CHIEF EXECUTIVE

The chief executive in an organization is usually termed "Managing Director," if he is a member of the board, or, "General Manager" when he is not a member of that body In both cases the primary responsibility is to implement the policies and the decisions of the board and to carry to it for decision those matters which are its province and prerogative

The chief executive must consider himself the trustee of the property of the shareholders, the guide of the management, and in conducting the enterprise he must always bear in mind the well-being of employees and the interests of society

His true function is making decisions, but they must be made with full knowledge of all the circumstances Without it his efforts to plan, organize, direct, co-ordinate, and control are not likely to meet with full success Directive management problems are always difficult, involving, for example, the selection of new ideas, patents, markets, and processes Decisions require the impartial weighing up of a large number of factors, and must be made expeditiously, though accomplishment may be deferred for years

The chief executive of a firm is always looking ahead, and in the execution of his special function, an economic adviser can often render considerable service Policy is, of course, determined by many considerations, but the more readily economic facts and trends are at the disposal of management, the more intelligent and trustworthy that policy will be The function of administration is to eliminate the element of surprise from business The successful business man anticipates the future, this is sometimes called flair, but generally means a sound perspective based on knowing the past and the present

In a manufacturing concern the higher executive consists of the chief executive and his immediate subordinates to whom he delegates responsibility for controlling the main functional divisions of the organization as in Fig 3

Only in the larger organization employing about 300 or more workpeople is it economic and practicable to appoint separate persons to these functions, but the principle also holds good for the smaller concerns where several of the main functions may be combined under one person, and where, in fact, the chief executive may control personally one or several of the main functional activities of his concern

The chief executive is the hub of the undertaking and is responsible only to the board of directors He focuses the interest of the board on policies and is the sole instrument by which decisions on policy are carried forward to the rest of the organization It is his function to take the initiative in moulding the form of the organization to meet the needs of the policies laid down by the board He must delegate authority to his subordinates in direct relation to the responsibilities they undertake and, if he is to be fully effective, and it is practicable to do so, he must leave himself completely free of detailed responsibilities so that he can devote himself to his own function which is that of leadership Freedom from detailed responsibility is also necessary so that he is free at any time to deal with emergencies and exceptional matters which arise and, further, so that his immediate subordinates may have complete freedom of access to him at any time

The chief executive must establish an organization structure, in collaboration with his subordinates, which clearly lays down the way in which he has delegated his authority to them and which elaborates their recommendations to him as to how their own authority is in turn delegated to their own subordinates down to the level of supervision of factory workpeople and staff workers. He must enforce this system of delegating authority by his own example in always working to it and by never "short-circuiting" the line of authority at any point excepting only in the absence of one of his principal subordinates and then only in conformity with prior agreement with him. Should it be desirable to interview anyone other than his immediate subordinates he must do so only in the presence of the immediate subordinate concerned unless the latter does not wish, or feel the need, to be present. He must not interfere with the functioning of the organization in any way apart from the channel of authority and responsibility which he has laid down.

In the small organization, the chief executive may not be able fully to carry such a policy into effect, but the principles involved are, nevertheless, equally applicable and the nearer he can keep to such a policy the more effective will be his leadership and authority. In the small concern too, the organization structure must, of necessity, be designed round the talents and latent aptitudes of the people the chief executive is able to gather about him, and a good deal of compromise is necessary in steering between established principles of management and the human factors involved. In large organizations, however, managing directors and their immediate staffs must require each other to sink individuality when the interests of effective organization are involved and to conform to patterns of responsibility and authority which are most appropriate for the concern as a whole.

The chief executive will usually conduct all his routine administrative functions at a periodic meeting of all his immediate subordinates and he will be wise if he ratifies at that time all interim decisions given between meetings By this means, each functional subordinate will have knowledge of decisions given to his colleagues, and which may affect him, and has a final opportunity of protest or elaboration All such decisions must be minuted in the records of the meeting and all executive action and all expenditures should find their written authorization in these records

IMPORTANCE OF MANAGEMENT

In recent years there has been a greater appreciation of the vital importance of management, and a belief that whilst some men have an innate gift of leadership, the fundamentals of successful management can be taught or imparted and latent ability developed, as witnessed by the inclusion of the subject in the curricula of universities and technical institutes, the growth of management societies, the larger number of conferences, and the increase of books and periodicals dealing with the subject Empirical methods of management have gone for ever Management is now something more than an art, though the personal element will always be the most important factor It is a highly skilled activity, the methods and underlying philosophy of which may be advanced by the application of scientific methods It is becoming a skilled profession, demanding not only high qualifications but preparation and training

EFFICIENCY OF MANAGEMENT

All firms are in the same market for materials and labour, and probably plant, differences in their costs lie in organization and the use made of time and the control of expenses Thus maximum efficiency in management is essential to economic survival

It may be asked whether it is possible to devise any measure of the efficiency of management It is difficult to suggest a criterion, for it can only be measured over an appreciable period of time and involves setting a standard on which there is little or no agreement The major function of any organization is to create and maintain a satisfactory profit The usual and obvious way of measuring efficiency is to compare the profits made by the enterprise with the average or representative profits made by firms in the same industry, but there are, of course, many other factors which enter into profits besides managing efficiency The true index is perhaps the ratio of profits actually earned to the real profit-making possibilities of the business There is, however, no one figure or ratio which can be taken as a pointer that the management is getting the optimum out of every £1 invested and every man employed Efficiency implies that the management is making full use of all agents of production A number of factors may be expressed as ratios and an overall view taken A number of these ratios were considered in Book I when the information obtainable from a balance sheet was discussed Others are—

Profit earned on turnover

Net profit on turnover

Volume of business to total capital employed, and so on

Profit or loss consists of two groups of items, those arising from manufacturing operations and those external to manufacture Ratios which more directly concern the works executive are operating efficiency, or operating profits on the capital employed, and trend of operating results, or cost and expenses over value of turnover We may say, however, that a works manager is being as effective as he possibly can when each department of the works is properly correlated with every other, and each division is working at a maximum efficiency He will continually be endeavouring to make the optimum use of materials, plant, and men, the most satisfactory materials for the purpose in view will be worked up without waste, machines will be continuously employed at the most efficient speeds, and the men will be working without interruption to a schedule which experience has established as a maximum that can be maintained without harmful long-run effects Planning is the keynote, each phase of the manager's duties will be directed towards raising or maintaining the effectiveness of the various agents of production It has been shown that high efficiency is developed in a works by supplying the men with the best procurable equipment, ensuring that they work under the best possible conditions, and supplying a wage incentive related to the quantity or quality of output

A high standard of management is no casual attainment but a complicated science, and in a works manager involves a sense of the economic process of production It is one thing to install efficient methods and another to prevent any slipping back into the old costly ways The point to remember is that efficiency depends on leadership

The corporate efficiency at which management must aim includes not only individual efficiencies and the association of efficiencies, but also the true efficiency which comes from enlightened reasoning and a higher motive There is no essential antagonism between the making of profits and full co-operation between management and employees

MANAGEMENT RESEARCH

Research is not confined to the laboratory or works, but should extend throughout the whole activity of a firm Management research is as indispensable as an economic weapon to keep abreast of progress as research on materials, equipment, processes, and designs Few errors could be more grievous than to stop research short at physical subjects and not pursue it in the science of management, works organization, and the human factor in industry, as well as in marketing, distribution, and other branches of the commercial division

A manager must continually modify and adapt his procedure to the ever-changing panorama of industrial, legal, and economic circumstances Hundreds of firms throughout the country must be confronted with the same or similar management problems To ensure contact with the most recent managerial procedures in practice, interchange of experience and cross-fertilization of ideas is not only desirable but essential, and most easily achieved by membership of one or other of the Management Research Groups

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CHAPTER II

THE PERSONNEL FUNCTION

THE practice of establishing a separate department to handle all matters relating to the employment, welfare, health and safety of employees has not been generally adopted until recent years The growth of the practice is, however, an indication of the acceptance of much greater responsibility for the care of employees on the part of industry than was previously considered necessary With the growth of labour legislation and the increased complication of agreements arrived at through joint negotiation machinery, together with the conduct of the joint negotiation procedure itself, specialization in this aspect of industrial management has become, in any case, inevitable If progress in this direction has lagged behind the need, this must undoubtedly be attributed to the lack of suitably trained personnel able and willing to undertake responsibility for the new personnel departments that have been created throughout industry

The chief personnel officer in any industrial concern carries a very wide range of different responsibilities calling for an equally wide knowledge of industrial relations and industrial legislation as well as of wage payments procedures and the organization and the processes of the factory itself (see Fig 8) But undoubtedly his greatest qualification must be his interest in, and understanding of, human nature, since if he performs his function effectively every personal problem in the organization should reach him It is his task to relieve the other executive personnel within the concern of the problems of recruitment, selection, training, welfare, and health of the employees allotted to them, so that greater and more specialized and more consistent action can be taken in these matters

It is sometimes suggested that the advent of a personnel officer detracts from the authority of the executives and supervisors carrying responsibilities for operation of the concern, such a situation should, however, never arise if the personnel function is established as a "staff" relationship to the rest of the organization as shown in Fig 2 In this case the personnel officer is in the position of an adviser to his executive colleagues who will in almost all cases have final responsibility for decisions taken in respect of the staff they employ, and it is found in practice that once this kind of relationship has been established, the personnel officer, even if he is only of the smallest help, is frequently in demand Where this relationship is established, it is also important to note that it can be unwise to give the title of "Personnel Manager" to the officer concerned since he will not, in fact, be "managing" the whole of the personnel of the company and such a title may, of itself, damage the clear line of authority which may be the official policy of the directors of the concern

The object of the personnel department is to provide and maintain the supply of human labour, skill and other abilities necessary for the successful operation of the concern, to see that disputes are avoided, that the highest standard of morale is achieved and maintained throughout the concern, and that employee turnover is reduced to the practical minimum set by local and other external conditions

EVOLUTION OF HIRING AND "FIRING"

The changing character of industry is well illustrated by the evolution of methods of hiring and "firing" This is obvious on comparison of the old-fashioned methods with those of a modern employment department which is open at all times and under the supervision of a manager appointed for his human sympathies

Before considering modern employment methods, emphasis must be placed on the fundamental importance of the personality of the personnel officer He must possess tact, good sense, intuition, courtesy and optimism System is not enough, the first contact of recruits with the firm must be right or relations may never be right Labour administration is always difficult and requires ability of the highest order

In the past, the works manager or the foremen appointed as well as controlled the workers, but when works grew too big for this method of appointment, the officials concerned being too busy with production, personal contact was lost and in large concerns the personnel department takes the place of personal knowledge of the workers

RECRUITMENT

The personnel department is primarily an aid to production Its first duty is to provide labour in the quantity and of the quality required by each department of the concern The personnel officer must be conversant with all possible sources of supply, with a view to selecting the best obtainable

If employees are to be retained in the service of the firm they must be adjusted to their jobs Labour absenteeism and turnover are frequently due to maladjustment at work The personnel officer must be well versed in scientific interviewing and methods of vocational selection He must examine not only the physique, general intelligence and aptitude of an applicant for the work in view, but also the temperamental qualities which influence his attitude towards work and life Many firms have introduced psychotechnical examinations before entrance and have obtained a better type of employee and a more stable working force as the result

LABOUR TURNOVER

One of the duties of the personnel department is to reduce labour turnover to a minimum Labour turnover is usually measured by

$$\frac{A + S}{E}$$

where A = the number of accessions during a given period
S = the number of employees leaving
E = the average number of employees during the period

With a high turnover the cost to the firm is serious, as practically every employee has to be trained and the expense of training young or new employees may amount to £60 each or even more The reasons for an employee leaving may be divided into (1) the operative's fault, (2) the firm's fault, (3) unpreventable Analysis of reasons for leaving have in many cases indicated that 75 per cent were theoretically avoidable, e g unpleasant conditions, disagreeable job, unrest, others leaving, bad selection By inquiry into the causes of labour turnover the personnel officer may be able to effect reductions and thus assist in the stablization of production

Analysis of the turnover will indicate whether the cause lies with the employee or the management If a worker is lazy, incompetent or insubordinate, it is obviously to the benefit of the firm that he should leave, but if turnover is due to bad wages or conditions, hazardous shops, or unjust or incompetent management of whatever grade, it is the duty of the personnel officer to bring the facts to the attention of the chief executive In the old days it was seldom possible for reasons of dissatisfaction to be brought into the open, but with the modern personnel department, employing scientific selection and guidance, matching the worker to the job, supervising education and apprenticeship, and exerting a steadying influence on discipline and disputes, there is a greater opportunity of establishing and maintaining good relations, unmarred by individual departures from the tenets of good management

EDUCATION AND TRAINING

Management has not only to select and place, but to train, promote and encourage employees Training is a continuous process, an insurance for the future Various schemes of education of industrial employees are available in conjunction with the local education authorities The personnel officer must organize the firm's apprenticeship scheme Some large firms have apprenticeship schools of their own, others have schools of instruction in specific jobs The whole subject of increasing the individual proficiency and productivity of the works employees, including the foremen, comes under the purview of the personnel officer

Training is frequently limited to consideration of training for a job, whereas it should be extended to include training on a job, not only because production methods are evolving rapidly, but because each employee should be engaged on the highest class of work of which he is capable Educational facilities should be provided and linked up with the firm's promotional scheme, and their use encouraged

PROMOTION

As regards encouragement, nothing—including even in some cases the financial inducement—stimulates like appreciation and conveying to the employee he is doing useful work For this reason, promotion should be given to men of proved ability and loyalty whenever practicable It is assumed, of course, that the employment officer's knowledge of sources of supply includes the existing organization It is very discouraging to the works force if an undue proportion of appointments go to newcomers The personnel officer should draw up promotion plans, of which the best known are the three-position plan in which everyone is considered as an understudy and a teacher, and the multi-chain plan embodying alternative directions of promotion Next to good wages, stability of employment makes a good job in the eyes of operatives, and the personnel officer can add appreciably to regularization of employment by arranging transfer of labour, with dismissal from the firm's employ as the last resort

JOB SPECIFICATIONS AND MAN SPECIFICATIONS

One of the objects of the personnel department is to ensure efficient and economical investment in man-power To this end some firms determine the essential factors in a specific kind of work and with this analysis before them endeavour to fit into the job workers having the requisite qualifications for its efficient performance In practice, job specification cards are drawn up stating the work to be performed, the knowledge of equipment and tools necessary, the physical characteristics or skill qualifications required, the hours, method and rate of pay, the wage increase or promotion possible, whether training courses are necessary and, if so, the type and length, and so on

Following job analysis involving statement of duties and conditions of work, the main factors in the job are set out, e g skill, previous education, previous experience, responsibility involved, physical and mental effort required In this way is brought out not only what the job requires an employee to have, but also what it requires him to give

After engagement the system may be followed up by a personnel rating scheme by which the employees are periodically rated or valued so as to see that each is not only doing the type of work for which he is fitted but the best work within his capability The scheme facilitates standardization of wage levels throughout the works, introduces uniformity in wage rate advances, forms a basis of training and job progression, and proves a great help in promotional plans Ability is not overlooked, but outstanding men are advanced in graded progression

RECORDS

It is evident that the personnel officer has to keep a large number of records, in fact the department is largely a recording office When help is required in the works a request should be made on a form giving as far as practicable the job specification All applicants have to fill up an application for employment form stating their training and experience The department keeps an employment record of each employee giving the result of medical and psychological examinations and particulars of the operative's progress with the firm, the manager's rating of the man and reasons for transfer, promotion, leaving and so on National Insurance records, First Aid Cards, etc, are kept in the department

Records are of two kinds—employee records and group movement records

With a view to envisaging the position of the working force at a glance, the personnel officer will chart the key factors, such as numbers employed, turnover, sickness and absenteeism and accident rate and severity He will, of course, use his data as a means of research to the benefit of the employees and the firm He will carry out a labour audit and issue a review or report at regular intervals

Conditions of Work

Personnel management is greatly concerned with the conditions of employment in the factory Under this heading come health and hygiene, accident prevention and relief, ventilation and lighting, lavatory and washing facilities, heating, noise prevention, rest periods and, in fact, all conditions relating to material and physical welfare

It is evident that the employment manager must have an expert knowledge of factory legislation and the regulations of local authorities, though he will consider these requirements only as a minimum, and, in fact, the provisions of most firms far exceed the legal minima

Welfare Services

Employees' welfare services under the care of the personnel officer include the works canteen, medical and dental supervision, recreation and social activities, libraries and clubs, the works magazine, industrial thrift plans, sickness and superannuation schemes, housing and other financial assistance schemes for employees

The personnel officer may also exercise a useful function in connection with the firm's suggestion scheme If he acts as organizer and secretary of the Awards Committee, he can not only help the employees, but being in one sense their representative, he assists in engendering confidence in the scrutiny of, and awards for, suggestions

EMPLOYEES' REPRESENTATION

As we have seen, the purpose of the personnel department is to ensure systematic and proper attention to all matters relating to the labour force with a view to establishing and maintaining successful industrial relations Recognition is given to the fact that workmen and women differ widely in desires, impulses and attitudes and must be handled with thoughtful care and treatment, justice and fair play, which is not inconsistent, however, with uniformity of policy throughout the organization The personnel office will take long-range views for the development of employees as individuals as well as efficient workers

In addition to engagement of labour, conditions of work and security of employment (as far as practicable), he is concerned to some extent with hours and wages With regard to the former he will see that they are reasonable apart from legal requirements, with restricted use of overtime, and he will co-operate in time study and the adoption of the most effective type of wage incentive The manager will, of course, be fully conversant with the Truck Acts and Trade Union or Wages Council regulations He plays an important role in the organization of management-employee relationships, not as representative of the employees but in a consultative capacity In practice he serves as secretary of the committees and council which constitute the structure of joint relationships or co-operative dealings in the firm This may be organized as follows—

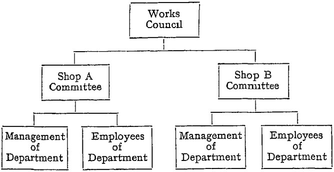

FIG 21

The committees envisaged are Safety, Health and Working Conditions, Education and Recreation, Avoidance of Waste, Thrift, Insurance and Pensions, Efficiency, including suggestion schemes and financial incentives, and, perhaps, Discipline, Grievances, and Hours and Wages Proper means must be established for carrying out the committees' decisions In this way, in so far as representative government is practicable in industry, the employment manager ensures the successful working of industrial democracy

In relation to trade unions the personnel officer will recognize and work with them, insisting on loyalty in adherence to agreements, and remembering that most of their ideals are noble and their conceptions right, as, for example, their great pioneering work in voluntary schemes against unemployment and sickness Welfare work is not intended to undermine the solidarity of labour, but to promote loyalty instead of hostility and engender a real corporateness and joint sharing in material prosperity

INDUSTRIAL PSYCHOLOGY

Reference has been made to the use of psychological tests in the selection of labour to distinguish those who do and those who do not possess qualifications and aptitudes necessary for a particular kind of work Discussion of the methods, types and validity of such tests would take us too far afield, but their success depends on the way they are used as well as on their merits This is, however, only one direction in which the psychologist can help the industrial world, and the work of the Industrial Health Research Board and the National Institute of Industrial Psychology must be studied fully to appreciate the contribution of the psychologist to industrial efficiency at reduced human cost Not only does he endeavour to ensure that the workman is doing the work for which he is best fitted by his aptitudes and abilities, but also under conditions eliminating wasted effort and needless irritation and fatigue and in an atmosphere of understanding and goodwill

The study of the effect of the factory environment on the bodily and mental health of the worker has proved a rich field for securing optimum results as regards both output and the economical use of human energy

Considerable light has been thrown on fatigue, monotony and accident proneness by the psychologist with ensuing reduction of accidents, sickness, labour turnover and spoiled work, and an increase in output, efficiency and happiness of the workers

The personnel officer will be conversant with the psychological limitations of a man as a working unit and will employ as necessary the experts to adjust the machinery and conditions of labour to the operatives' capacities, remembering above all that mental causes are basic in amicable industrial relations, and industrial efficiency is dependent on contentment He will organize the Safety First movement in the works in the light of the fact that the majority of accidents are caused by failure in the human factor

It will be noted that the position of manager of the personnel department is one of increasing scope and importance His principal functions are to obtain an adequate supply of personnel and to control the conditions affecting personnel These two main functions have been subdivided in the foregoing into (1) engagement and follow up of labour, (2) health and safety of employees, (3) education and training of labour, (4) employees' services, (5) employees' representation, and (6) employment research It will be noted that under all these headings an intimate knowledge of various sections of industrial legislation is required In addition to the further basic qualification of a sound training in industrial psychology, high personal qualifications are required, as the personnel officer must be liked and trusted by both management and men

THE SPECIAL POSITION OF FOREMEN

The evolution of industrial organization has developed the foreman's position from that of leading craftsman to that of supervisor of his department's activities, it remains a key position in any industrial concern At no time in industrial history has foremanship called for a higher grade of intelligence and training than to-day The foreman may, in fact, be compared to the commissioned officer, responsible for the smooth running of his unit However much planning has been accomplished, the foreman is responsible for obtaining results His job is co-ordination in the workshop with due regard to the relative importance of all factors in efficient production He must be capable of analysing the work in order to have all parts of the equipment continually active and a steady flow of work through the department maintained He must co-operate with the stores department as regards materials, the machine-tool department as regards tools, and with the plant engineer He must be able and willing to teach and to co-operate with the training department, if there is one He must inform the progress department if difficulties occur which may cause delay in delivery, and must advise the management if their instructions seem likely to produce results which they apparently had not foreseen The foreman must possess a cost sense in relation to the use of machinery, tools, materials and time, and also do his best to assist the cost office by ensuring accuracy of records, as regards not only direct, but also indirect, charges.

The foremen play an important role in the efficient control of their departments. It must be remembered, however, that under scientific management, before they begin to exercise their function, the department has been planned, the sequence of processes laid down, the operation rates fixed, and the standard of workmanship required has been determined. The foremen are responsible for maintaining the required rate of production of the specified quality and at the minimum cost. They must have a knowledge of many branches of work which do not fall within their responsibility in order to secure co-operation between their departments and the whole organization.

The importance of the foremen lies in the fact that they are responsible for the immediate management of men. They must lead and inspire, not drive and dismiss. They are in intimate contact with the workers and interpret the firm's plans to them and, conversely, the workers' views to the management. Of all factors affecting the worker the quality and type of first line supervision is the most important. If labour's first contact with executive authority is not on a satisfactory basis, difficulty is likely to arise in carrying out the management's plans. The comparative failure of scientific management in many American plants has frequently been attributed to the tyranny of the functional foremen. The importance of the careful selection of foremen and training them in the leadership of men, whatever type of organization is adopted, needs no emphasis. Nor must the contributions which they are able to make to the stock of managerial knowledge and successful operation of the enterprise be overlooked.

By encouraging suggestions and displaying scrupulous fairness, they may be able to utilize the latent capacity of the workmen and effect improvements of considerable value to the enterprise The day-to-day experience of the foremen must be made available to the management Opportunities should be made to learn their views, and on works committees their abilities and services can often be utilized with advantage Properly handled, they can render great assistance in propagating and maintaining the proper spirit of organization and creating the right atmosphere in the shop by disseminating loyalty, sense of duty, and enthusiasm throughout the working force Personality and leadership constitute a very important aspect of a foreman's qualifications To possess the ability to handle men combined with practical knowledge is by no means common, it requires a character which inspires confidence and trust, and it is considered that this should constitute a primary requisite in choosing foremen

The foreman also holds a key position in making safety work successful The responsibility for training apprentices and educating the workmen may also rest upon him, and he should continually plan to keep every man enthusiastic as a means of maintaining the efficiency of the department

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CHAPTER III

THE DESIGN FUNCTION

DESIGNING and drafting is usually one of the major functions in any manufacturing concern The quality of a product depends on the efficiency of its design, the quality of the materials used and the quality and accuracy of the workmanship involved in its manufacture It will be seen, therefore, that the first consideration is to get the product right on the drawing board, here the key-note is simplicity consistent with efficient service The second point involves the establishment of standards, and the third demands the spending of time, thought and money on inspection

QUALITIES OF A DESIGNER

If the design of a product is not right, the work of the other departments is wasted or inefficient Moreover, in the highly competitive markets of to-day the designer must be much more than a skilled draughtsman He must have a flair for commercial success, imagination, vision and inventiveness, but at the same time a sense of design from the manufacturing point of view This combination of the appreciation of manufacturing and commercial value is rare, but necessary to enable the designer to keep the balance between the works manager and the purchaser on the one hand who are concerned with minimizing costs and the sales manager on the other, who is always pressing for better quality, finish and efficiency

The designer must always bear in mind the effect of design on costs and have a sufficient knowledge of the work of the shops to evolve a design requiring the most economical manufacturing procedure However carefully designed a machine may be and however fully it meets mechanical requirements, it may be commercially worthless if in fact it cannot be sold at a profit On the other hand, a machine need not be scientifically perfect if it will fulfil the purpose for which it is designed This must not mean, however, that the machine will be so shoddy that the cost of maintenance and after-service will be exorbitant

The designer must have a knowledge of materials which will permit him to select those most readily and economically worked He must be conversant with the machines available and their capabilities so as to adapt designs to ready and cheap performance, and so that the operations may be carried out on those having the lowest machine-rate to carry in overheads He must use standardized components wherever possible as this affects the runs of work and reduces assembly costs He must not only be able to design jigs and fixtures, but understand the economics of their employment

It is evident that the key-note of the designer's job is co-operation, not only with the shops but also with the remainder of the organization

The designer must co-operate with the sales department as the salesmen know the needs of prospective customers, receive suggestions for improvements from buyers, learn of faults in service, and obtain information on the products of competitors

The departments responsible for the production of the drawing-office designs must be specially considered Designs must be submitted to those who have to reproduce them with a view to utilizing their knowledge of cheap and rapid processes, preventing the use of costly tooling operations, avoiding the cost of special machines, and so on

If the progress department finds that delays arise on the schedule for certain parts, the designer must first see if modifications cannot be made for more rapid manufacture before extra plant is considered Although he specifies the materials, the designer must co-operate with the purchasing department for lowest all-round cost

With the estimating department the designer will co-operate on new projects, and also with consulting specialists if such are employed

Some engineering firms have resident engineers on a project, and these will, of course, gain experience of inestimable value to the designer Similarly, the designer's attitude to users of his firm's products must be one of co-operation

Being correct to start with is so important that no opportunity for consultation before finality is reached should be lost with a view to lowest overall costs consistent with satisfactory service

The reports of the inspection department should be studied to see if the rejections or the reasons for rectification are associated with any fundamental weakness in design

Factors Influencing Design

Besides taking into account the mechanical problems involved in economical manufacturing methods, the designer will be concerned with the safety of the operator of the product and its ease of handling in the plant and on shipment There are also many other points to which his attention should be directed from the sales point of view, such as the influence of pleasing lines and finish, floor space occupied, accessibility, flexibility and easiness of control, "fool-proofness" and low upkeep and service costs

In the past there has been a general tendency in British engineering designs towards unnecessary weight and rigidity, whereas lightness and ease of handling might have been attained by simplification without sacrifice of safety

Design Department Organization

The evolution of product design involves—

1 Research and experimentation

2 Preparation of functional drawings and design on scientific lines

3 Construction and test of experimental prototypes

4 Analysis of experimental prototype performance

5 Stabilization of design in preparation for production

6 Analysis of design for simplification, standardization and production methods

7 Detailing of production drawings

8 Preparation of master tracings

9 Checking and authorizing issue of manufacturing drawings

10 Liaison with works to ascertain adjustments revealed to be necessary during production

11 Supervision of assembly and test of production prototype

12 Issue of final design amendments

13 Full scale test of pilot production model

14 Release to production for full scale output

The management structure of a medium size design department in engineering manufacture may be similar to that illustrated in Fig 4

STANDARDIZATION OF DESIGN

Lack of use of standard parts and of interchangeability of components has in the past been an irritating and wasteful fault of designers The designer must guard against the use of needless patterns and different sizes of screws and bolts, and must employ, wherever practicable, similar parts in different types of machines so as to permit manufacture in economical quantities He must use standard materials if possible, employ standard limits on working drawings and avoid needlessly fine tolerances Examples of standard units which may be used are governors in steam engines, differentials in cars, ignition units and starters The designer must have a thorough knowledge of the advantages of standardization in relation to its economy, for example, in jigs, fixtures and tackle

CONTROL OF DESIGN

Working drawings are a record of the product as finally designed and made. Drawings should give every particular and be subdivided into units, showing one component only. One machine must not be held up because the drawing is in use at another.

Classification and identification of drawings are important for ease of reference. They may be listed alphabetically or numerically or by a combination of these methods, and corresponding patterns, components, subassemblies, etc., should bear the same code number. If changes in design are made, all outstanding blue prints must be recalled and the code number altered. A list must be kept permitting location of every blue print issued, e.g. Consequential changes must be carefully studied, for example the effect on tools, patterns and fixtures.

Blue Print No	Issued to	Received by	Date	Recalled	Returned	Recalled	Destroyed

FIG. 22

Reference may be made to the use of preliminary models in design, not only for visualizing the proportions, but for determining clearances and the relative motion of parts and to test operating characteristics.

DESIGN AND MANUFACTURE

It is a truism that the draughtsman must see his design through production spectacles, but his knowledge of processing may not be called into play until an experimental or research design has been made and tested for mechanical efficiency. This stage in the development of a new product may require months of intensive work. When the new product has been proved satisfactory from a technical point of view, the design will have to be gone over again, component by component, from the production point of view A slight change in design may make it possible to use parts interchangeable with other jobs Redesign of a beater bar in grinding machines enabled the same bar to be used in different sizes of machines involving less dies and less stock Tools, gauges, and jigs will have to be designed with an eye on ultimate costs and not first costs This is an important aspect of designing and is referred to more fully under the heading Tool Engineering (Chap V) Data for purchasing, manufacturing operations and quality standards will have to be provided Materials will have to be selected with a view to a steady flow of work, designs for foundry work will not have to be of impossible thinness or of a type which cannot be drawn from the mould, drawings will have to show all the requisite information clearly so as to avoid delays in the shops, specifications will have to be precise, and all drawings and specifications will have to be issued in advance of the scheduled start of manufacture

Examples of the practical workshop knowledge required by the draughtsman include allowances for shrinkage as in dies for forming hot metal, in bending sheet metal, and in grinding or finish machining work, the avoidance of unnecessarily intricate moulding or machining operations

EFFECT OF DESIGN ON COSTS

A cost-reduction sense is essential in the drawing office, and a steady team effort should be exerted towards lowered costs of production An important factor is simplification, from many points of view the simplest is the best The draughtsmen must keep abreast of changes in manufacturing methods so as to substitute cheaper for more expensive operations Improvements in materials must also be carefully followed Change of design may be dependent on the availability of better materials, e g greater strength and durability of steels for dies, punches, etc , permit materials of greater thickness to be pressed, stamped, or formed

Savings arise from very simple changes such as the way in which sheets are cut or laminations stamped from strip The welding of pipes together to form a line is cheaper than using flanges, or when flanges are essential it may be cheaper to weld on the plate type instead of screwing them on The use of flame-cutting instead of machining must also be kept in mind

In practice it is more generally a question of redesign to reduce costs than starting with low-cost designs Simple examples include the simplification of radio transformer bodies so that bent aluminium strips could be used instead of castings, and the redesign of a spade handle so that the operations were reduced from seventeen to nine and the total cost per handle reduced 80 per cent

The effect of design in connection with machining costs may be illustrated as follows—

In the first design of a bearing support, it had to be chucked for turning, and then re-chucked for boring, with a final difficult grinding operation

A second design was got out in which the whole of the machining was done in one setting, but the grinding operation was still difficult

A third simplified design was then made by which the whole machining was still done with a single chuck, but all the operations were easy and accessible and the cost was considerably cheaper

In a well-known flexible coupling, change of design of the teeth from curved to straight teeth caused a reduction in machining costs

There may be economy in the machining of small parts from material trepanned from large parts

A change in design of a machine base was made which permitted it to be built up of angles and bars instead of castings being used The welded machine base proved 37 per cent cheaper to make

The design of a portable electric drill was altered to permit the use of pressed-steel casings and other parts instead of aluminium cases The parts were punched and formed in presses and spot-welded in jigs to ensure interchangeability In quantity production, the cost was reduced by at least a third and the weight also proved less

By altering the design of a small casting to make it a pressure casting, instead of a moulded job, the cost of the die was saved on the first 200 off

Loading coil pots were reduced in size and weight, made more durable, and the manufacturing time reduced by changing the design so that sheet metal could be used instead of cast-iron

Other examples of changes in design to permit more economic methods may be cited in making wheel hubs of pressed steel, differential gears by upsetting one end of an axle shaft, ball-bearing rings by upsetting them from plain bars, and so on

Reference should be made to the limit of the rate at which it is economically permissible to incorporate changes in design of manufactured products In a firm making special sizes as well as standard products it is advisable to try out a change in design on those sizes of which only a few are made A change in a standard line made in large quantities may prove an elaborate undertaking, involving perhaps jigs, fixtures, special machines and processes The disclosure of an unsuspected weakness after mass production has commenced would prove a serious matter

STANDARDIZATION

Standardization dates back to the beginning of history, speech, writing, measurements, time and weight being the basis upon which civilization developed Fundamental standards are appropriate for the Government to establish Industrial standardization, with which we are concerned, is of much more recent origin and based on mutual consent and co-operation of all interested parties It signifies the simplification and unification of the requirements of industry by the collaboration of the producer, the merchant and the user This bringing together of manufacturer, distributor and consumer to modify their requirements by agreement focuses the best thought and practice, and the co-operation and unity of action engender constructive forces which tend to eliminate waste and yield fruitful economies

Industrial standardization is a natural step in the scientific development of engineering and is merely carrying specialization to its logical conclusion The wastefulness of a great number of individual specifications and a wide diversity of patterns and sizes is readily appreciated Moreover, everyone is aware of the great difference in price between standardized and non-standardized articles such as boots, clothes and motor-cars, tin boxes, etc

Standardization is the basis of interchangeable manufacture and of mass production and probably the greatest economic factor in the growth of the engineering industry during the present century

Standardization has a greater scope in parts and components than in finished products, and it is more difficult to introduce into old-established than into new industries owing to the large invested capital that might have to be scrapped or the heavy investment required to carry out a thorough-going scheme

Moreover, owing to the principle of voluntary standardization, unwise standards cannot be forced upon an unwilling industry or public There is no danger of standardizing anything simply for the sake of standardization Once industrial standards are established they do not preclude improvement, advancement or innovation and the introduction of new processes Frequent and careful reviewing of industrial practice readily permits such changes as may be desirable The preparation of a standard specification necessarily involves the pooling of a large amount of technical knowledge and experience not otherwise obtainable, and, in addition to the confidence thus generated, the same knowledge and experience are best qualified to indicate when a standard is obsolete or obsolescent

SIMPLIFICATION

Simplification means the elimination of unnecessary varieties of a product, in the sense that they cannot be justified on economic grounds A single item or part is used for as many purposes or classes of product as possible The number of patterns, sizes and styles is reduced to a minimum The continuous production of a few types saves the starting and stopping of expensive machinery, and the waste of time in set-ups and changes of materials In addition to longer manufacturing runs and higher production rates, simplification results in less capital being tied up in stocks and less storage space, in fact, it introduces many sources of economy The work of the British Standards Institution in this direction is well known, so that only a few examples need be given, viz steel sections, tramway and colliery rails, haulage ropes, electric cables, telegraph poles, studs, bolts and nuts, washers, etc

The motor and cycle industries provide an excellent illustration of how simplification of types and standardization of components have increased efficiency at greatly reduced prices

Simplification also modifies the sales technique, i e sales have to be achieved on quality (relative to price), not on novelty

AIMS AND OBJECTS OF STANDARDIZATION

The objects of industrial standardization involve the determination of suitable dimensions, qualities, types and performance and the establishment of performance tests These increase production and facilitate maintenance, and result in reduction in unit costs Interchangeability is advanced and efficiency and safety in use are increased In manufacturing, standardization aims at savings in production time from continuity and system, and the economy that arises from large-scale production

In the past, trade has been handicapped by lack of precise knowledge of technical requirements or performance, insufficient stocks and poor methods of distribution Standardization aims to simplify buying and selling, provide adequate stocks or prompt delivery, and facilitate and cheapen distribution

FIELD OF STANDARDIZATION

Industrial standardization covers a very wide field, including—

1 Nomenclature or the setting up of standards for definitions, terms, symbols and abbreviations It is considered that this classification of terminology is the correct way to start any systematic standardization

2 Dimensions The fixing of tolerances and allowances is the basis of assembly and interchangeability The inconvenience and waste of multiplicity of dimensions and lack of standards of form and size are well illustrated by screw threads before Whitworth's work The standardization of such items as wire and sheet gauges, sections, threads and connections has obviously been invaluable The dimensional specifications of the B S I are related to the various industries

3 Quality of materials This is of interest to all industries In some cases the composition as well as the properties of materials is specified The specifications indicate the permissible minima These standards assist production in many ways, facilitating buying and inspection and a uniform flow of work during processing Although standards multiply as new materials come into industrial use, there is not only a desire but a trend to a minimum number of standards This section includes standards of sampling, analysis and testing

4 Tools and equipment This, of course, is based on No 3 F W Taylor took thirty years to standardize simple lathe tools, partly because there was no standard tool steel to start with Standardization is, of course, extended to drills, reamers, milling cutters and taps and dies, grinding wheels, belting, and so on Built up logically and enlarged step by step, the system is extended to complete engines, motors, and other equipment, e g specifications for triple expansion marine engines, boilers, oil engines, cranes

5 Processes If tools and equipment are standardized, there is a possibility of standardizing methods or the most efficient way of doing a job in the light of present knowledge In addition to the scope in mechanical processes, standards have been drawn up, for example, on the determination of the fusing temperature of coal ash, baking varnish, drawing office practice, street lighting, etc

6 Performance or rating of machines to show, for example, whether a so-called 100 h p electric motor will do what is claimed for it Standards have been drawn up of the performance of generators, motors, converters, transformers, engines, etc

7 Safety, e g the factors of safety in design, construction and installation in a crane Considerable work has been carried out by the Standards Committees, in some cases at the request of the Home Office, and with the active support of industry

ADVANTAGES OF STANDARDIZATION

Standardization permits the manufacture of a more regular, reliable and, in some cases, improved product at a lower cost It expands demand and broadens markets By permitting the accumulation of stocks during slack periods, it exerts a stabilizing influence on production and employment or minimizes the ill-effects of seasonal demands by levelling up the labour load It reduces manufacturing costs in many ways Less machinery is required for a given output, time is saved in set-ups and re-assembly, the turnover is increased and overhead costs reduced It simplifies clerical and costing systems, supervision and inspection and the instruction of employees It renders available large supplies of materials and labour in an emergency

The expense of carrying stocks, of maintenance and of repairs is reduced There is less idle capital in fewer patterns and sizes The development of more efficient machinery and new methods is facilitated and greater interchangeability of parts is encouraged Complicated operations are minimized, and there is reduction in the cost of preparation of drawings, specifications, and tenders Delivery is, of course, expedited

Standardization suppresses confusion merely for sales effect , the work of the salesmen is facilitated and selling costs are reduced Fewer mistakes are made in ordering, the supplier really knowing what the intending purchaser requires There are fewer misunderstandings in trade, as the purchasers know what they are getting

DISADVANTAGES OF STANDARDIZATION

Standardization to some people suggests a dead low level of uniformity and monotony, the retarding of invention and design, the elimination of individuality and the cessation of progress Stagnation of design and crystallization of practice may make changes difficult to achieve It is suggested that the growth in repetition work involved degraded the workers into mere machine workers and accelerates the disappearance of the craftsman Moreover, as our standards may not appeal to the foreigner, standardization militates against meeting the requirements of export markets In so far as these suggestions contain latent possibilities, it is essential to guard against standardization stultifying progress and hampering trade There is no virtue in the mere desire to be different, but there is as yet little danger of standardization being carried to extremes

STANDARDIZING ORGANIZATIONS—BRITISH

In 1901, on the initiative of Sir John Wolfe Barry, an Engineering Standards Committee was formed by representatives of the Institution of Mechanical Engineers, the Institution of Naval Architects, the Institution of Electrical Engineers and the Iron and Steel Institute This Committee appointed sectional committees which called in representatives of the Admiralty, the Board of Trade, the Classification Societies, manufacturers and independent experts, and approached the work in an orderly manner It was found that there were about 300 different sections rolled in British steel works and the work of simplification started Standard test pieces, methods of testing and standard tests were decided upon, the first list being published in 1903 By 1905 there were thirteen sectional committees and 250 persons on sub-committees

In 1918 the Engineering Standards Committee was incorporated as the British Engineering Standards Association In 1929 a Royal Charter was obtained, and the main Committee became the Council A demand for an extension of scope led to a supplementary Charter in 1931, and the British Standards Institution was formed with a General Council and Divisional Councils for engineering, building and chemical industries and provision for a Textile Council The work of the four main divisions is subdivided into industry committees, which supervise about 600 specialized technical working committees About 3500 engineers and business men form the representatives on the technical working committees

The engineering industry committees cover aircraft, chemical engineering, colliery requisites, electrical, gas, plastics, illumination, iron and steel, mechanical, non-ferrous metallurgy, petroleum and public works with about 175 technical committees and many more sub-committees

The preparation of a British Standard specification is only undertaken if, in fulfilment of a generally recognized want, producers and users are prepared to co-operate and the necessary funds are forthcoming Standardization must be arrived at by general consent and periodical review and revision must be undertaken Any individual or group of individuals has a right of appeal to the Divisional Council and then to the General Council if there are any objections to provisions in a specification

The work of drafting the specifications is in the hands of the technical working committees The widest possible scope is given for comment and criticism Catalogues are available covering about 600 specifications The economic value of the work is widely recognized and millions of copies of current specifications are in circulation

The Handbook of Information issued twice a year gives a list of B S I specifications and particulars of new specifications in preparation The annual report gives particulars of the Institution's work during the preceding year

The whole of the technical assistance and funds of the Institution is obtained by voluntary contributions from the supporting organizations and the sale of its publications with the addition of grants from the Government, the Crown Colonies and India

DOMINION STANDARDIZATION

National standardizing bodies in close liaison with the B S I exist in all British Dominions, but not in India, Australia alone having about 500 technical drafting committees There is an interchange of final draft specifications for examination and comment

The Imperial Conferences in London in 1926 and 1930 drew attention to the necessity for the co-ordination of specifications within the Empire, and the Ottawa Conference in 1932 gave a further stimulus to imperial standardization with a view to the encouragement and increase of trade

INTERNATIONAL STANDARDIZATION

Differences in language, units of measurements, and in trade practices are barriers in international trade A number of specifications have been translated into French, Italian, Portuguese and Spanish, and the Institution keeps in touch with the requirements of foreign markets to assist British export trade Probably only nomenclature can yet be profitably discussed from the point of view of international standardization, but the Institution keeps in direct touch with the work of the International Federation of National Standardizing Associations The Electrical Industry Committee is also the British National Committee of the International Electrotechnical Commission

Other international standardizing bodies, besides the International Federation of National Standardizing Associations, are the International Association for Testing Materials and the International Commission for Testing Electrical Installations

International standardization liberalizes commerce in the manufactures concerned

STANDARDIZING ORGANIZATIONS—FOREIGN

American legal standards are under the charge of the National Bureau of Standards formed in 1901 The American Standards Association is the national voluntary organization comprising some 600 member-bodies It works in close co-operation with industrial organizations such as the American Society of Testing Materials, the Society of Automotive Engineers and the American Institute of Electrical Engineers At the present time there are more than 900 standards in use and about 450 tentative standards

In Russia standardization has an important place in the plan for national economy under the control of the All-Union Scientific Research Institute of Metrology and Standardization, the present methods involving co-operation between industry and consumers The number of approved standards exceeds 5000 Complete plants are being designed on standard lines to meet the demands of various industries

EXTENSION OF STANDARDIZATION

We are mainly concerned here with engineering standardization by national bodies, but it must be remembered that the principles of standardization may be extended within a firm beyond the regions covered by national specifications Scientific management is based on classification and standardization, not only of materials, machines and products, but also in operations and procedure Operation standardization depends on the determination of the most efficient movements and processes, followed by time studies with a view to introducing standard procedures, performances and wage rates Without standard performances compilation of production control boards or charts would be impracticable

The advantages of standardization apply to other business functions than production, and its effect is to be noted in safety provisions and in office procedure, e g in records, accounts, forms, etc

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CHAPTER IV

THE SALES FUNCTION

IN Book I, under the heading Market Analysis, we have noted that the sales forecast is the starting point of a firm's projected activities The effectiveness of sales organization is undoubtedly one of the main factors in a firm's progress since variation in profits will depend to a great extent on the accuracy of the budgeted sales figures An engineering sales department is a complex and variable organization with internal and external functions In accordance with the general rules laid down for good organization the exact scope of each individual's duties and activities should be known to all The general lay-out of the sales organization of an engineering firm making products for home and export markets might be as shown on page 93 The intelligence service may include market research and liaison with trade associations

The sales manager is the keystone of the sales department He will, of course, be guided in his policy by the managing director of the company, but he must be a man of initiative, ready to propose new policies as opportunity offers He must be active, energetic and persistent in order to cope with the onerous work of sales promotion, which consists of exploring the possibility of obtaining new customers and markets and discovering new products to be manufactured, as well as consolidating his position by retaining accounts He must be an energizer, heartening and putting fresh life and interest into his sales staff confronted with resistance difficulties, as they well may be, for example, in the face of severe competition

It is essential that the sales manager be a good judge of human nature, a good "mixer," and know how to handle men—not only clients and prospective customers but also his competitors whom he will be meeting at trade and

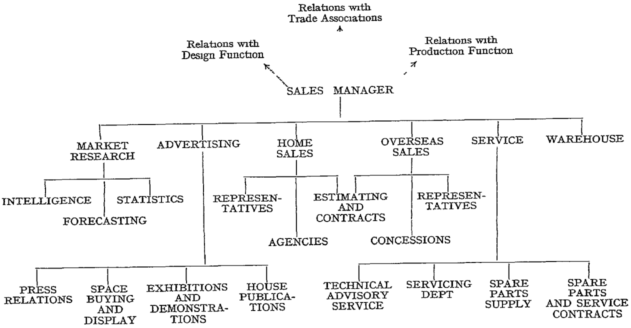

Fig 23 Organization of Sales Department for an Engineering Firm

association meetings He must understand the psychology of the industrial groups to whom he sells He must be a good organizer, otherwise he will be unable to tackle the hard work required to utilize fully the efforts of resident and travelling representatives and agents both at home and abroad, with whom he must keep in close personal touch They are the eyes and ears of the firm and their reports must be closely scrutinized It is a good practice to have meetings of all representatives at the works at regular intervals when they can be instructed in the latest sales position, policy, and requirements, as well as bring themselves up to date in knowledge of the firm's products and capabilities

Whether the sales manager should also be a technologist is a difficult question There is only one test of salesmanship, and that is to sell The primary duty of the sales manager is to get results, and there are so many factors in salesmanship besides knowledge of product that too much weight must not be given to technical qualifications Many non-technical men are successful sales managers of engineering firms, but owing to the increasing technicality of business, it seems advisable for the higher control always to bear in mind the advantages that might accrue from training and promoting a young technical man who can demonstrate an aptitude and flair for salesmanship

A further requisite of the sales manager is helpful co-operation not only with the accounts department but with the works

A special reference should perhaps be made to co-operation with the production control department The latter is, in a way, the servant of the sales department From a commercial point of view there is no virtue in merely producing an article, it does not effectively exist until it is in the hands of the user or customer Some firms have a progress clerk in the sales office whose duty is to keep track of delivery promises, advise the works departments of the urgency of the sales department's requirements, and peg away to see that promises are kept in the dispatch of work This clerk's work is superfluous with a properly organized production control department, as we shall discuss later Progress work requires a specialist and a man of standing in the firm However persevering the clerk referred to might be, the works would probably go their own sweet way If the firm has a live and efficient production controller, the sales department can get all the information it requires for correspondence or handing on verbally to customers by merely lifting the telephone and asking him The sales department places before the production control department the customer's point of view, and the production controller endeavours to meet it, or, if impracticable, is able to say what is the best that can be achieved, and it is then the duty of the sales department to translate this into terms understandable by and acceptable to the customer It is fundamental to the relations of the sales function with production that no delivery promises are given to the customer which do not emanate from the production control department

ADVERTISING

Publicity and propaganda are the life-blood of sales Engineering publicity is a highly specialized activity. The sales manager will decide the selling policy and the sales campaign, though he will not do the detailed work of advertising and circularizing

Until recently, technical advertising was somewhat awkward, hesitating and amateurish owing to insufficient study of the persons to whom it was addressed and its precise purpose Purchasers of engineering products are usually technical experts or under scientific and technical control, and to approach them it is necessary to adopt means that will appeal to the technical mind Claims that cannot be substantiated must be avoided, and only such information presented as is based upon careful tests and accurate research Purchases are made only at fairly long intervals and after careful investigation, so that whilst the design and careful lay-out of advertisements are important, it is convincing technical information which induces action The results of tests and technical diagrams are usually read with interest It is a mistake to put a deal of copy in an advertisement, as it is confusing, but care should be taken that the name of the firm is unequivocally associated with the product A bold, sure handling of advertising gets people to believe in the firm's products The greatest appeal in advertising is the economic one, as technical products are bought on their cost per unit of satisfactory service, in other words, engineering products are sold exclusively on their utility and economic advantages A demonstrated or proved increase in the output of the user is a good selling point in engineering advertisements

As between standard products and specialities it is advisable to emphasize in the first case any proof of superiority over other makes and in the latter any proof of advantages in service

An important medium of advertisement is the technical journal, which is a clearing house for news in a particular industry The advertisements need only interest those who can influence the purchase of the products, but it will be found that impartial descriptions of products and plants, and details of installations and unusual applications, are of interest to those engaged in the industry who look through the advertisements to keep up to date in improvements and implement their knowledge of the trade

Another valuable medium is the firm's catalogues and data books These are tending to become treatises and books of reference The effect of booklets, folders and bulletins is not so transitory as that of journal advertising, and they are in some cases sought after by users of the particular class of product as they give data and particulars of practice long before they can get into technical textbooks They have the advantage that they can be sent direct to prospective customers and give confidence to buyers by demonstrating how exhaustively and thoroughly the product has been studied

The advertising appropriation of engineering firms usually includes an item for exhibitions These attract business men, including those from abroad, anxious to keep up to date in the particular industry and taking advantage of seeing a large part of a given market assembled under one roof The exhibiting firm can not only show changes in design but demonstrate improvements in working methods To get the best value out of the expenditure, the firm must have technical representatives continuously in attendance to give advice and demonstrations, solve the problems of present or prospective clients and take part in the technical conferences usually held in association with engineering exhibitions Some buyers may suggest modifications, and thus new designs may be accelerated A proper set of reports must be sent to the sales manager for subsequent action

The cost of publicity should be budgeted in advance, and the budget will depend on market research, as discussed in Book I (Chapter XII) When deciding the advertising appropriation a campaign will be laid down based on the prospective sales volume, but, of course, subject to revision As a rule isolated advertisements are worthless

The examination of trade and technical journals is an important feature in sales promotion On the one hand, the advertisements of Government Departments, municipalities, etc , indicate their requirements for tender, and a routine must be arranged for all tender forms of interest to the firm to be written for On the other hand, the articles in technical journals will indicate new uses or outlets for the firm's products Details of contracts placed, formation of new companies, erection of new works and various other news extracted from technical journals may also prove of interest to the firm

SALES CORRESPONDENCE

Too much importance cannot be attached to correspondence, as a letter, in a way, carries the reputation of the firm with it, and may be the only means a prospective customer has of judging what kind of people he is going to deal with Incoming letters must be acknowledged on the same day as they are received if a complete answer cannot be given by return All sales department's letters must be tactful, courteous and helpful, and every client must be made to feel that his inquiries are appreciated If it is found that promises cannot be kept with regard to delivery date or other matter, the client must be advised at once, and wherever practicable the real reason for delay should be given In other words the sales correspondent must realize that he is dealing with business men who have their own commitments, and it is not very helpful to them to be told that delay is due to unforeseen circumstances Such threadbare *clichés* are only galling

Even more important than a practical explanation is to advise the client what delay is involved so that he can alter his own plans and programme accordingly

STATISTICS

An essential function in the modern business world is to keep in touch with the rapid change in commercial and legal conditions One of the duties of the sales manager will be to maintain contact with the trade associations to which his firm belongs and embody their policies in his quotations

In the organization diagram a statistics section is indicated The general advantages of statistical control have been referred to in Book I (Chapter VII) A sales department cannot function properly without them The essential facts that must be compiled will be affected by the nature of the business, but the following will undoubtedly be included—

Total sales and their trend

Sales of individual departments, comparisons and trends

The sales cost for each period divided into its constituents (representatives' salaries, commissions, advertising, circulars, exhibitions, etc)

The sales of each representative or district

New accounts, their value and trend

Bad debts and their distribution

Stocks and their trend

Statistics have to be kept in detail with regard to sales records Some firms prepare a summary of the transactions with each customer showing the date of each inquiry, a brief report of the representative's call and the order with its value Such record sheets obviate going through the whole correspondence and in any case may have to be prepared if the dealings with any firm have to be brought before the higher management Such sheets are of service in showing up dormant accounts, then to estimators they show previous quotations, and they are also of service for the collection of accounts if the financial standing of the customers is included in the records

The file system of a sales department is usually large, and whilst, as a rule, arranged alphabetically, a geographical file may be of service in sales promotion and in dealing with the work of the representatives

The statistics section will be associated with the market research section The fundamentals of market research are described in Book I, Chapter XII The methods adopted by makers of capital goods such as engineers will differ in detail from those of firms making consumers' goods

TECHNICAL REPRESENTATIVES

Engineering inquiries may be highly technical or involve intricate specifications The representative of the manufacturing firm receiving them has to meet the customer or perhaps the consulting engineer acting for the latter Inquiries from abroad are frequently sent to the London branch of the foreign company, and the London manager may be the only man in the country with a working knowledge of the foreign plant The engineering firm's representative will have to go into the details of each inquiry, and if necessary obtain explanations of the requirements before it will be practicable to prepare a design or submit a tender It is evident, therefore, that the representative must be a technical man or possess sufficient technical knowledge of materials and operations and have sufficient practical experience not only to understand but to deal with the inquiry He must be able to detect if it is possible to modify part or whole of the inquiry in such a way that it can be tackled more easily and expeditiously in the plant of his firm, or if the design can be improved, or if there are better and cheaper ways of carrying out the project He will bring these matters to the attention of the customer, showing how they will affect the price He will put his firm's technical experience at the client's disposal with a view to achieving a solution of the inquiry which will be the most economic in the long run and therefore redounding to the credit of his own firm in technical circles

After an order has been placed, the representative must be ready for consultation whilst the job is being carried out and do all he can to facilitate and expedite its conclusion to the satisfaction of the client

It is important for the firm to keep the representatives up to date with information, including complete and accurate facts about the products, so that they can answer any reasonable question put up to them by customers This information may take the form of data books, preferably the loose-leaf type so that new information can be recorded concisely and added as required or revised when necessary The data books may be supplemented by a bulletin giving information which the representatives can utilize, such as improvements or enlargements in the firm's plants, data on competitive products, or advantages that have recently come to light with regard to the firm's own products, changes in prices or discounts, alterations in stocks or deliveries, notes as to slow or fast-moving lines, notices as to large or important contracts received, or any other information that will assist the activities of the sales force

FOREIGN REPRESENTATIVES

A problem frequently arises as to the best type of man to choose for foreign representative or manager of a foreign branch Should he be a man sent out from the head office, and if so should he be selected for his technical knowledge owing to the distance he will be from the works, or should he be selected for his salesmanship and commercial knowledge or for his social standing? On the other hand, ought not he to be a native of the foreign country? Apart from the language difficulty, can an Englishman understand the mentality of purchasers and the psychology of buying in a foreign market as well as a native? Will the engineers and other purchasers open up their mind to him as they would to a member of their own race? Will they not be more secretive to an Englishman who will have greater difficulty in understanding and forecasting the trend of events?

It is widely considered the better practice to place an Englishman in charge of a foreign branch and let him exert his ability to choose native assistants of the right type This usually ensures that the interests of the parent firm are better safeguarded and the central policy more likely to be carried out In any case, however, a member of the higher executive should make regular visits as frequently as practicable, not only to study the position, but to familiarize himself with the special requirements of the country, to call on important customers and prospective clients, and to ensure a live and intimate connection between the firm and the foreign market

SELLING PRICE

The fixing of selling prices of a company's products is clearly a responsibility of the sales organization Decisions must, however, be based on information received in the form of estimates from the cost accountant—a matter which we shall consider in detail in Chapter X

In many cases, of course, information as to the cost of production will be fundamental in arriving at a selling price but, in any case, it is a matter of sales policy to determine the margins of profit for distributors, wholesalers and retailers if these channels of distribution are involved In the engineering industry it is often the policy to have a domestically organized and controlled system of distribution, and here again sales policy determines commissions to salesmen and agents

The sales department also must control and apply any system of discriminatory discounts which may be allowed in certain divisions of a market in conformity with company policy and also determine selling price variations according to quantities ordered

Other circumstances where sales policy may make deviation from the strict adherence to basic estimates of production costs are in the case of trade agreements coupling trade standardization of products with price stabilization And if a strong policy of domestic standardization of products is being followed it may be necessary to use selling price discrimination to give the customer a strong incentive to accept a standard line of product in place of special characteristics which he may consider desirable to his special requirements but which are by no means essential to the effective operation or serviceability of the product

TENDERS AND SPECIFICATIONS

A tender is a written offer to do work or to provide goods at a definite price, and if accepted there is, of course, a contract We have discussed contracts in general terms in Book I (Chapter VIII), and noted that they are agreements between persons competent to perform a legal act The essentials of a contract and the alternative methods of its discharge were considered The following notes refer more particularly to engineering contracts

In the case of a trading company a written note signed by a person under the express or implied authority of the company is sufficiently binding A letter accepting the tender will (with the tender) constitute a contract Each tender should contain the manufacturer's specification and a printed list of conditions of sale From the purchaser's point of view it should contain a clear statement as to liability for non-fulfilment of performance, and for damage in transit and maintenance during the initial period of service, and from the seller's point of view the terms of payment required

As in tendering a manufacturer offers to supply goods and to perform work in accordance with the conditions of contract, the legal significance of each must be understood Conditions of contract usually contain references to the following—

1 Quality, e g to be in accordance with drawings and specifications or approved samples

2 Defective Work Whose decision is final?

3 Date of Completion, e g as and when specified in schedule

4 Damages for Non-delivery Liquidated or agreed damages?

5 Variations Whose sanction is necessary if permitted?

6 Fair Wages Clause The rates of wage and hours of labour must not be less favourable than those locally recognized by Employers' Association and Trade Unions

Such a notice is to be exhibited at the works

No sub-letting is permitted unless customary

7 Inspection of Work, e g permissible at all reasonable times

8 Injuries to Workmen Liability for

9 Corrupt Gifts Reference to Prevention of Corruption Acts, 1899–1916

10 Decisions Reference to Arbitration Act, 1950

11 Patent Rights Indemnification of purchaser

12 Bankruptcy, e g automatically terminates the contract

13 Payment Terms of

Unless the standing orders under which a public authority acts provide otherwise, notice of a contract to be placed by the authority must be published and tenders invited (The Local Government Act, 1933)

The specifications used must define fully and clearly the requirements, for example—description of plant, its duty, testing, erection, delivery, conditions at site, materials covered by British Standard Specifications and the limits of the contract in relation to other contracts

Model forms of general conditions of sale are available and recommended by the leading engineering institutions The contract with a public authority will comprise the specification, the general conditions, the accepted tender, and the memorandum of agreement

As mentioned above, in some cases contracts to be placed by public authorities must be advertised The advertisement will declare the general description of the work and the approximate quantities, where to apply for form of tender, specification drawings or plans, the character of the bids desired, the person to receive the bids, when and where, the conditions of payment, the security required if any, and the right to reject bids Bidders get all their information from the drawings and specification, and if properly drawn up it should be unnecessary to ask for additional information

Specifications may vary from bare outlines to elaborate statements, but they should in any case be expressed in simple and exact language The specification must not be too rigid It is inadvisable when dealing with machinery and plant exclusively to specify components or auxiliaries With regard to design, a clause should be included permitting "other approved design" It is preferable to specify performance rather than physical and mechanical requirements as this allows diversity of raw materials and makes possible improvements to mutual advantage

In regard to the form and arrangement of the specification, the general clauses as to responsibilities and terms generally precede the specific clauses as to design and construction

In specifying machines of standard design, the requirements may be set out in great detail, but for special machines the specification should go no further than general description and conditions The specification will contain particulars as to inspection or survey and usually it contains a clause that the work is to be completed to the satisfaction of the engineer or agent

It has been said that the tender form and specification should be clear and definite They should be well written but not literary The bidder should examine all clauses carefully, and set out his offer equally clearly The tender should be submitted by the due date or it will not be considered It may be useful to recapitulate the most important points requiring attention—

General description
Particular description
Conditions of sale
The limits of the contract
Are drawings or samples to be submitted?
The requirements as to inspection, testing or performance
The conditions of acceptance
Packing and dispatch
Delivery, place, date and order or progress of work
Conditions and procedure for extension of time
Terms of payment
Responsibilities of the contractor
Storage if necessary
Damage in transit
Guarantees
Penalties for non-fulfilment
The purchaser's right to suspend
Arbitration procedure if necessary
The legal construction of the contract

In examining tenders the following points should be clearly noted—

Prices Are the prices quoted net or are discounts allowed? What packing charges are required and by whom is carriage paid?

Terms To whom are accounts to be rendered?

Packing Are cases returnable or non-returnable? How are packing cases to be marked number, weight, address, etc ? Are packing notes to be enclosed? Is packing for export shipment to be shown separately?

Delivery To whom to be delivered, any limitation on method of delivery or times? Commencement and rate of delivery?

Advice Notes How are the goods to be described? When are advice notes to be posted, and is one required per consignment?

Inspection Is any notification required when goods are ready? Where and by whom are they to be inspected? What tests are required?

Guarantee Over what period? What defects involve replacement? Should any be defective, will the remainder of the consignment be rejected?

In regard to machinery tenders, attention should be given to the following—

How many days after acceptance of tender must adequate drawings be in the hands of the purchaser?

By whom are foundations to be erected and on whom is the onus of their being correct?

Who is to supply the labour and materials for erection? Approximate figures for labour cost are $\frac{1}{4}$ to $\frac{1}{3}$ of manufacturing labour and oncost 30 per cent Alternatively 15 per cent on works cost for heavy plant and 20 per cent for light plant

Are running tests to be made at the maker's works before dismantlement for shipping?

What tests are to be made after complete erection on site?

How are the parts to be protected during transit?

How is the machinery to be painted?

What provision is to be made for spare parts?

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CHAPTER V

PRODUCTION FACILITIES

THE provision of facilities in the form of site, buildings and equipment is clearly of basic importance in considering the organization of production In this Chapter we shall be considering all the more important physical provisions which must be made to enable production to take place and certain methods of organization which equally may be classed as production facilities, irrespective of the type of production method or type of product involved

FACTORY LOCATION

The manufacturer about to establish a manufacturing business will usually have a choice of locations His aim is, of course, to find the optimum from the point of view of long-run profits, having regard to each aspect of the business, i e availability of raw materials, the actual manufacturing process and sale of the finished products Technical, commercial, and financial considerations are involved and the object sought is the location, site, size, and scope of production which will yield maximum returns

The following are the principal economic aspects of plant location, though Government direction, trade treaties, subsidies, special forms of taxation and other restrictions disturb these economic considerations to varying extents from time to time

1 *Availability of raw materials* Proximity to sources of raw materials is the obvious explanation of the location of some of our old industries, e g the early localization of the iron industry in Sussex and its subsequent migration to the north of England Other illustrations will occur to the student, such as pottery in the Black Country, chairmaking in Buckinghamshire, and so on In modern times, however,

immediate access to raw materials has become of diminishing importance

2 *Proximity to markets* The advantage of being near the centre of demand for the finished products, or alternatively at a good distributing centre, needs no emphasis Not only is the firm and its products likely to be better known but the cost of distribution is an important item in overhead expense, and as between two firms having equal manufacturing costs, it may be sufficient to give the nearer firm a competitive advantage With the increasing importance of the marketing agent, the growth of localized industries is thought to have been halted The recent growth of light engineering and semi-luxury trades near London, however, is largely due to advantages to be derived from such a concentrated market and such a good distributing centre by sea, road, rail, and air Another factor is the ability to give quick service to customers

3 *Transport facilities* We have seen from the above that freight paid on raw materials and finished materials enters into the costs of production, and in recent times transport facilities may well be the governing factor in economic location Transport costs may, in fact, force plants, however mechanized, to be near a consumer market For firms handling heavy products, water transport is usually essential In this connection we may note the location of the Ford factory on the Thames, not only in connection with incoming coal and iron, but on account of proximity to London and Continental markets For firms with an important proportion of foreign trade in Empire and world markets, proximity to docks is a valuable factor Within the country the chief modes of transport are rail and road In recent years railway companies have shown themselves more accommodating in regard to the provision of private sidings for industrial firms The low cost of motor-truck haulage has, however, made it a strong competitor in industrial transport It has, of course, the advantage of door-to-door delivery Its effect may be

seen in the location of an increasing number of factories alongside arterial roads

4 *Availability of power and fuel* Last century the localization of industry was largely influenced by the necessity for proximity to the coal-fields as transport costs were high, but whilst some plants still require large quantities of fuel for heating and process steam, the development of electrical power for industrial use and the construction of the high-tension grid system of distribution have had a centrifugal action and assisted the establishment of industrial plants away from the fuel sources Unfortunately this country is not well supplied with hydraulic power, but the localization of aluminium and other plants on our few resources is accounted for by the cheapness of this method of generating electrical power The partial development of the grid system for distributing gas under the new regional gas boards also has a contributory effect in assisting the decentralization of manufacturing industry

5 *Climatic and atmospheric conditions* Climate as between parts of the British Isles is not an important factor The classical example is the localization of the cotton industry in Lancashire, but with the great strides in air-conditioning it is possible, and frequently economically practicable, to control the atmospheric moisture content in any factory when this is necessary Of course the farther north, the greater the cost of heating a factory adequately throughout the year, and most concerns avoid a locality where the atmosphere is contaminated with fumes which may be deleterious to the product or greatly increase the costs of upkeep and maintenance owing to corrosive attack

6 *Availability of labour* In choosing a location regard must be given to the possible or potential supply of suitable labour, not only as regards amount, but the right kind and obtainable at the right price Some industries require highly skilled labour, others unskilled but intelligent Obviously the former type might be difficult if not impossible to obtain in rural areas There is a tendency to locate

works where a large and settled population provides plenty of skilled and unskilled male and female labour Cheap labour is not necessarily low-paid labour, but there are some industries which cannot pay high wages and must consider districts where female as well as male members contribute to the family income

7 *Momentum of an established industry* If an industry has obtained an early start in a district, there grows up in it a body of skilled and expert workpeople with a special aptitude for the class of work possibly developed over generations The district acquires a reputation for high quality which has a real publicity value Specialization of the district helps to localize institutions engaged in research and centralizes progressive work there Even if some of the original advantages of the location have passed, momentum may carry it along, and community of interest prove more attractive to a manufacturer than erection of a works in another part of the country Incidentally, there may also be satellite concerns in the locality which have been developed to take the waste or by-products of the main industry

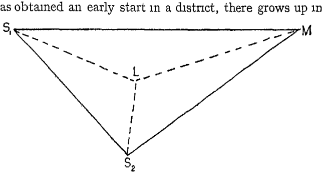


FIG 24 DIAGRAM ILLUSTRATING THE DETERMINATION OF THE MOST PROFITABLE LOCATION FOR A FACTORY

8 '*The preference of outstanding business men* There seems to be no explanation but a personal one to account for some locations, such as the manufacture of cars at Oxford, windows at Braintree, and so on Preferences of

industrial executives is undoubtedly an important factor in area development

9 *Good water supplies* Apart from the advantages of water transport, an abundance of water may be required for cooling purposes in power houses, and purity of water may be essential for some industrial processes, softness of water for others An example is the use made of the Liffey water at Dublin or the Don water at Sheffield

Item		Charge per Unit at Site			
		S	S_2	M	L
Raw Materials	(a) (b) (c) d/d				
Fuel and Power	Coal Electricity Gas				
Works Expense	Labour Superintendence				
General Expense	Administration Taxes Insurance				
Distribution	Packing Transportation Sales				
Total Cost per Unit					

FIG 25 TABLE TO DETERMINE THE LOWEST COST SITE

To illustrate the factors involved in finding the location of greatest profit, in Fig 24 let us assume the following simple case of two sources of supply S_1 and S_2 of raw material and one point of consumption or marketing centre M Let L be the location of the manufacturing plant Then it is obvious that if L is at M only freight on raw material will be paid, or if L is at S_1 or S_2 there will only be delivery charges on the finished product, if at an intermediate point, both incoming freight and outgoing delivery charges will have to be paid In practice a comparison would be made of each constituent of the total cost which would be involved if the plant were erected at each of the alternative sites, as shown by way of example in Fig 25 The location which involved the minimum total cost per unit would, in the absence of any other overriding policy considerations, be chosen as the site for the plant

Attention has been focused of recent years on the dangers that may arise from the uncontrolled and unrestricted growth of great centres of population, particularly London, including problems of public health, communications, vulnerability in war, and so on, and it has now been decided that the growth of such centres must be controlled with a view to securing a more even distribution of production as part of the full-employment policy of British government

In the early days of the Industrial Revolution, the localization of industry was mainly determined by proximity to cheap power and accessibility to raw materials due to difficulty of transport Specialized regions arose having a central basic industry, which whilst possessing advantages, some of which have been referred to above, also suffered greater fluctuations than districts in which the work was diversified

As time goes on, new processes render existing trades and occupations obsolete, and revolutions in transport make whole districts obsolescent Other causes of obsolescence of a locality include—

1 Antiquated plant

2 Exhaustion of old sources of supply and the discovery of alternative raw materials

3 Rationalization

4 Trade barriers, protection subsidies, and national self-sufficiency

5 Nepotism in administration

In the last half-century the electrical industry has been responsible for the growth of light engineering at the expense of the earlier heavy mechanical engineering work These developments have tended to alter the distribution of industry in the country

Cheap power requires, however, the centralized control of electrical distribution as well as generation, as it is essential for the establishment in this country of new manufactures such as ferro-alloys and calcium carbide

In Book I (Chapter IV) we noted the shift of industry northward to the coal-fields following the application of generated power to factories, and it is evident that the present age is characterized by a shift of industry back southwards again South-east England is now the most important industrial area in the British Isles Some of the reasons for this southward trend of industry are apparent from the above considerations

The magnitude and density of the population in and around London constitute the largest concentrated market in the world as well as an enormous labour reservoir The growth of industry in Greater London is in fact due to proximity to its immense market of 10 million people, in spite of the cost of land, building restrictions, difficulties of transport and travel, and severe restrictions in regard to noxious fumes and trade effluents Improved transport facilities, both rail and road, in and around the metropolis, have, however, helped to open up many new industrial districts and also permit workers to live some distance from their places of employment London is a first-rate seaport and airport and a substantial part of the country's aeronautical industry is centred round it Its financial and commercial facilities are unrivalled Developments in electricity generation have brought adequate power to London and its surroundings and made them attractive to manufacturers of an extremely wide range of products

URBAN *v* RURAL SITES

The value of factory sites has to be considered in relation to factors affecting production and factors affecting sales In the former are included land cost, availability of labour and accommodation therefor, the cost and availability of coal, water, and electricity, the degree of efficiency of deliveries to the factory, and the possibilities of revised factory lay-out Amongst the latter we have transport costs of distribution, telephone costs and other services, accessibility to customers, advertising value of the site, and availability of staff

In a town there are sure to be good rail and road connections for collecting and distributing A good labour supply will be better assured, housing, municipal services, public health, and education will be developed Power and water will be readily obtained from the local authorities The town site will have a good advertising value, for not only will more persons pass it, but the urban council will probably carry on an advertising campaign of the town and its industries There will be technical and commercial schools for training operatives and staff Financial and commercial facilities will arise from the aggregation of business men

On the other hand, land values in urban areas will be high if purchase is contemplated or alternatively the price of leases and rents will be higher than in the country Rates will also be heavy and the wage level higher than in rural areas There will be less possibility of expansion due to the probability of the urban area being built up

Amongst the advantages of country sites are cheap land and low rates, lower wages due to lower cost of living, lower insurance charges due to less fire hazard In the case of industries which can only be housed in one-storey buildings, the economic advantage of the low land values will be considerable and an ample margin can be allowed for expansion In the country there are also as a rule fewer restrictions in building

The supply of labour may, however, present difficulties There are fewer social amenities in the country, and even if a large firm finances a housing scheme for its labour the attractions of town life are very strong to operatives who have once dwelt in cities Moreover, as there are less likely to be subsidiary industries, working-class families may have to break up so that all members can find work Housing certainly constitutes a problem in the country, even if a firm arranges transport facilities there is little doubt that operatives prefer to live near their work Nevertheless the distribution of factories into rural areas would have definite social benefits for the ill-effects of overcrowding of the working population in towns are too well known to require discussion here As stated, the increasing speed of transport allows people to live farther from their work, and town planning with satellite residential areas will prevent, in future, factories being jumbled up with residential quarters There is a tendency for trading estates to be constructed on which industrial premises are segregated and laid out with full amenities for power, transport and communications The success of these trading estates may be an indication of industrial planning in the future

The mention of the rise of trading estates—initially intended to encourage new types of industry in areas hitherto devoted to older industries—on which buildings may be erected to attract industrial occupants raises the question of buying versus leasing a factory, which has received considerable attention in the United States The cost of operating a factory at a planned industrial centre may be less than on an isolated site Whilst a firm is usually established to last indefinitely, the progress of technical knowledge and invention is so rapid that it is impossible to say exactly what some firms will be making a few years ahead For firms which cannot foresee a continued demand for their products, investment in a lease may prove more economic than in the ownership of a factory In this country, however, it is generally considered that if a company has sufficient money to buy its own factory and still leave a surplus to avoid the need of temporary loans, the advantage lies in ownership

Ownership is evidently advisable if the leases available are short and the cost of moving equipment is high, or if a highly specialized factory is required there is probably no alternative

The reason that a firm moves to a new site is usually that its work is expanding so fast that it cannot be housed in its existing premises A warning should, however, be raised against moving to a large and expensive site The management should make quite sure that reorganization and rearrangement and improvement in materials-handling equipment will not ensure the increased capacity desired before deciding to erect a larger and expensive factory elsewhere Production cannot be accurately predicted very far ahead and there may be danger in the optimism of temporary success

SELECTION OF SITE

In passing from the general locality to the actual site further considerations arise It should be suitable for the satisfactory lay-out of the buildings and the processes of manufacture Main storm-water and soil sewers should be near the site Allowance must be made for expansion, or in a few years the plot of land may be rendered unsuitable It should be freehold and free from all encumbrances A careful survey of the projected site is necessary as any latent disadvantage entails an expenditure for all time Is there any sunken stream crossing the site or any sewer or pipes or tunnels carrying cables? Is the subsoil suitable for foundations and drainage? Is it possible readily to dispose of trade wastes? It must be remembered that a level site is not necessarily the best for a satisfactory lay-out It may have to be excavated for processes to be carried on at lower levels On the other hand, on a site that is not level lay-out will be facilitated in a plant in which gravity conveyance is inherent in the process In some cases a low-lying site is advantageous, but swampy ground increases the expense of laying foundations and building costs Careful examination must be made of the title deeds to see that there are no encumbrances on freehold property, rights of way, or way-leaves It is expensive when any flaws in the title are discovered afterwards Local building laws must be carefully studied and it must be ascertained if any town planning schemes or projected road widening will affect the site

Land values must be critically examined in the light of possible appreciation and capability of industrial development The questions of ground rent, rates and taxes, legal restrictions, and financial facilities of the district will require attention

As regards the receipt and dispatch of goods, a river site is advantageous for coal and other mineral transport and usually solves the water problem, including fire protection, but it must be remembered that more will be spent on painting the factory, and the fog nuisance is likely to arise If rail transport is to be relied on the factory owner should note that sidings are only taken from the slow track, goods loop, and near a signal box With regard to lorry transport, access to two roads is desirable Another factor is that whilst lorries have to be cleared immediately, railway wagons can be retained for three days

In considering power supply and services which may in some factories be the ruling factor, adequate electricity supply is usually available without difficulty and the necessity of generating does not frequently arise, though the nature of the industry and the size of undertaking have a bearing on this With regard to factories using gas, consideration should be given as to whether it is more economic to consume "town gas" or erect a gas generating plant The type of labour in the district must be studied with a view to obtaining the best kind of operatives for the work Is there sufficient housing in the district for the requisite quantity or can it be brought from a nearby centre if adequate transport is arranged?

FACTORY PLANNING

Having decided the location of a factory, fixed the immediate and potential capacity, and selected the site, it must be remembered that the plant is really a working tool—the most important of working tools, into which all others have to fit—and must be given the best possible conditions in which to function

There is no need to emphasize the necessity for planning a plant to obtain the most economical manufacturing sequence of operations and most efficient production methods, and, therefore, lowest costs In the past it has been known for a factory to be erected and no thought given to planning till things went wrong, it was then too late to prevent severe losses Planning a plant to ensure continual operating efficiency is no easy matter, and one in which experience counts for a good deal, plans which seem all right on paper often fail to stand the stress of practical everyday working

As the object of a manufacturing enterprise is to produce as much and as efficiently as possible, with a minimum total cost per unit, it is apparent that too much care and attention cannot be given to the lay-out, design, and equipment of the factory, and the handling of tools and materials consistent with the essential consideration that the investment must be warranted by the business available It must be remembered, however, that a factory is something more than the buildings and working tools It is a complex organization which takes in the raw materials and delivers the finished products, and in which the human element is prominent if not pre-eminent When, therefore, the term "maximum production" is used, it is intended to mean the greatest compatible with the well-being of the working force, and as experience has shown that human effectiveness is dependent on industrial environment, the economic importance of correct factory design and lay-out is further emphasized

BUILDINGS AND FIXED EQUIPMENT

The type of factory buildings, and production lay-out employed is decided by the kind and quantity of product, the class of materials handled and the production equipment necessary A factory building scheme requires the services of an industrial architect, since a distinctive modern type of industrial architecture has arisen, combining simplicity with sound and permanent construction The engineers of the factory must naturally co-operate, with a view to specializing and adapting buildings and shops, as there are certain matters upon which they alone can advise

A large part of the population spends about half of its conscious hours on work, much of which is monotonous, and the works architect endeavours to see that the work is carried on in a building which is convenient, cheerful, and of architectural quality He wants to know, however, the whole process of manufacture, so that he can produce a building which grows from the necessities and form of the machinery, a skin to protect the machines and the workers

Most factories require the following components—

The factory proper, including receipt and storage of raw materials, buildings for the various processes, storage and dispatch of finished products, research and testing laboratories, and also administration offices, canteens and welfare centre, including first-aid services

PROVISION FOR EXTENSIONS

In planning building schemes the possibility of expansion and development must be remembered The plans shown in Fig 26 permit extension in several directions from end walls whilst ensuring light wells for adequate daylighting Adaptability must be borne in mind not only in plan but in construction

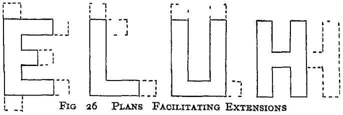


FIG 26 PLANS FACILITATING EXTENSIONS

FOUNDATIONS

The foundations of buildings call for particular attention They must be sound and adequate for the superstructure, especially for buildings subject to the constant vibration of machinery Whatever type of building is required, there must be, first of all, a good foundation and the bearing power of the ground must be ascertained If artificial foundations are required, reinforced concrete in the form of piles or rafts has been found very satisfactory for the purpose

It may be advisable to consult experts on questions of the prevention of transmission of vibration and noise It is cheaper to take precautions than to cure the nuisance afterwards Not only can machinery be isolated but soundproof buildings and structure can be designed if so required

Having laid down a comprehensive plan adequate for immediate needs and permitting extensions, the points that arise for consideration include the following the type of construction of the various departments, the floor materials and the number of floors if the buildings are not all of one storey, the supports for cranes and shafting, the methods of fire protection, ventilation and heating, the distribution of power and artificial light, the arrangements for laying lines for water, steam, gas, and compressed air, and the various special problems arising from the particular type of manufacturing plant

METHODS OF CONSTRUCTION

The principal considerations with regard to structural materials are strength, durability, safety, stability, speed of erection and cost The number and range of materials available for factory buildings are large and varied, and need careful selection to obtain those most suitable to the specific requirements of the plant The buildings may be of brick, with or without steel frames, or of concrete blocks, or reinforced concrete Special manufacturing operations call for departure from the ordinary type of construction Galvanized sheets may be used for light types of structure

Bricks are relatively cheap but costly to erect and are being largely replaced by concrete, which has caused much change and development in factory buildings

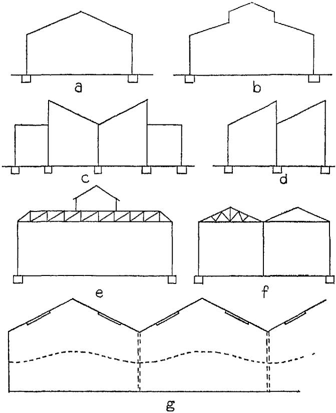


FIG 27 SECTIONS OF STEEL FACTORY BUILDINGS

The type of structures and the materials used will depend on the position of the factory and the effect of by-laws In the London area the L C C code of practice of relatively solid construction must be complied with

Steel-framed construction is almost invariably used in single-factory building Not only has the use of structural steel and steel joists increased for factory buildings but the all-welded steel frame construction is now available

In bay construction the span is determined by the floor area required for the most convenient unit of output in relation to the length available The M-shaped roof shown in (*c*), Fig 27, is suitable for foundries owing to the good natural draught

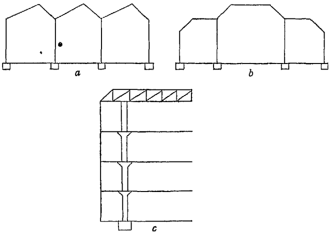


FIG 28 SECTIONS OF REINFORCED-CONCRETE BUILDINGS

Reinforced-concrete structures are quickly erected, low in first and maintenance cost, fire resistant, and very strong The advantages are, however, offset to some extent by the cost of subsequent alterations to the building or providing for channels and vents, and it should be remembered that the heat conductivity of concrete is about twice that of a plain brick wall

This material of construction is particularly useful for multi-storey buildings One storey may be added above another in a sort of mushroom construction as shown in (*c*), Fig 28

It should be noted that all factory buildings must comply with the Factories Acts, and should be in accordance with the fire insurance office requirements and the local by-laws

WALLS AND PARTITIONS

Many special materials are available for wall construction. rendered cement, asbestos cement, synthetic fibre boards, insulating blocks, and metal steel construction of various kinds Their costs must be considered in relation to the advantages for the factory in question The minimum capital outlay may mean the maximum cost of upkeep, but it depends of course on the purpose of the building The finish should be smooth and simple and ledges which permit the accumulation of dust should be avoided The materials must be studied for resistance to wear and atmospheric corrosion For factory partitions and screens, the chief desiderata are cheapness and rapidity of erection They may consist of asbestos-cement sheets, plaster or breeze slabs, or plaster board Doors may be top-hung for ease of opening and automatic closing, but in certain cases must open outwards to comply with the Factories Acts and fire protection requirements

ROOFS

Roof coverings may be slate, tile, galvanized iron, corrugated asbestos, or bituminous felt They should be light and cheap, but durable, resistant to the weather, and bad conductors It must be remembered that the heat loss from a factory roof may be as much as 50 per cent of the total

Saw-tooth roofs will be referred to below in regard to daylighting, but it may be mentioned that roof-glazing largely consists of ¼ in rough cast or wired glass The longer slopes may be flat or corrugated steel sheets or even concrete slabs Spans are built up to 60 ft Concrete buildings usually have flat roofs which may be of the same material, lead, zinc or asphalt

Roofs must be adequately drained, and a point which well repays attention is care in gutter construction Steam pipes may be carried along in the neighbourhood of gutters if they are likely to freeze

FLOORS

Floors may be made from a variety of materials, from a sand floor to polished wood blocks—the type depending on the nature of the factory processes. Efficient flooring should possess a number of qualities, including durability, low thermal conductivity, silence, non-slipping properties, freedom from dust, ease in cleaning and repairing, loading capacity and low cost, but commensurate, of course, with the life or convenience expected. In making a selection between alternatives the materials should be rated under these or other headings with a view to choosing the best all-round material for the factory in question. The choice of flooring material does not always depend on durability.

Boarded floors are still widely used, or wood blocks on concrete foundations, especially where there is a danger of dropped parts being damaged. Where the traffic is heavy a hard dustless floor is required and a granolithic finish gives good results. An asphalt floor wears poorly, but is easily repaired, and is good for wet situations or where acid may be spilled.

Metal floorings resist wear indefinitely, but are light, conductive, and may be noisy. Chequered steel plates are safe and non-slipping. Water-cooled floors are necessary for special machinery, e.g. in rolling mills.

Many different tiles are available for tiled floors where necessary. They are easily cleaned, but are cold, and may crack and be difficult to repair. Alundum tiles are non-slipping and provide an alternative for dangerous positions, e.g. in front of machinery and on treads of stairs.

Before laying floors thought should be given to the passage of conduits and the holes through which pipes are to rise. Holes should be left in walls and floors to avoid cutting. All main services should be grouped and exposed, and painted in different colours to facilitate tracing.

SINGLE-STOREY AND MULTI-STOREY BUILDINGS

Industrial buildings are designed to perform a functional purpose and this will decide the type of building, e g if the manufacturing methods involve the gravity flow of products as in the manufacture of chemicals and paints, a multi-storey building is indicated, but for heavy work and products a single-storey building must be used In the latter case, as in locomotive building, the vertical flow of materials is ruled out

Where either type of building is permissible, an economic choice must be made by balancing the advantages against the disadvantages With regard to the site, for example, it is evident that for a given capacity the area of a single-storey factory must be greater than that required for a multi-storey factory, and, if land is dear, the latter will have an advantage in the cost of the site As it is usually stated that a single-storey building is most suitable when space is available, let us examine the advantages of this type—

1 Lighter foundations,
2 Less subject to vibration troubles,
3 Supervision easier and more effective,
4 Greater efficiency in routing and handling materials,
5 Greater flexibility with regard to lay-outs,
6 Less fire hazard—lower insurance charges,
7 Greater ease of isolating dangerous processes,
8 Simpler methods of expansion,
9 More effective floor area, free from columns,
10 No stairways, fire escapes or question of floor loads,
11 Better natural lighting—even top light, therefore width is not limited,
12 Lower cost of artificial light,
13 No power required for lifts and elevators,
14 A mezzanine floor will provide additional office or shop space

On the other hand the cost of heating and ventilating may be higher, the cost of roof maintenance will be more, longer ground runs are required for drainage, distances may be excessive for the transmission of mechanical power, there will be less convenience for water storage as compared with a lofty roof, and cleaning of window and glass-lights will probably be more expensive

On the whole, however, single-storey buildings are less expensive and there is a general tendency to use them, except in light engineering works where the machines and products are readily adjusted and handled in accordance with the floor arrangements

FIRE PROTECTION

The chief safeguard against fire lies in the use of fire-proof construction Fire prevention is more important than fire combating Factory buildings should, wherever possible, be built of fire-resisting materials, e g steel construction and ferro-concrete This also applies to party walls and partitions Exits should be provided with panic bolts and should swing or open outwards External fire staircases should not pass by windows The doors in party walls should also be of reliable fire-resisting materials Double doors give an added advantage Inspection is, of course, necessary to ensure proper functioning at all times Lifts and hoists should be enclosed in a brick or concrete well and have fire-resisting doors Superheated steam pipes should be suitably lagged where they pass through or near wooden partitions The equipment in cloakrooms should be of steel Special attention should be given to insulating those parts of a factory most subject to fire hazard with a view to minimizing the risk of spreading

Fire-proof construction, fire extinction and escape from fire are inextricably connected It is essential, for example, that staircases be made of fire-resisting material

The principal fire-resisting devices depend on an adequate and reliable water supply A ring main should be constructed to pass conveniently near to each building Two sources of supply are desirable and in each case the pressure should be adequate

Automatic sprinklers and drenchers should be fitted throughout the shops If freezing is probable the dry-pipe system may be employed, the water being kept back to the supply pipe by compressed air Each installation should be fitted with an automatic fire alarm Valves should be fool-proof and the system of fire extinction tested periodically, especially fire hose which may deteriorate unless under constant supervision The maintenance of fire equipment may be overlooked from a feeling of security, chemical extinguishers should be kept in accessible positions with clear instructions for use

Special precautions should be observed if combustible and inflammable materials are used and stored

Inflammable spirit, for example, should be stored below the level of the ground to prevent spreading Buildings should be constructed of asbestos slab and kept properly ventilated to prevent overheating or spontaneous combustion It is known that the latter phenomenon may occur in large heaps of coal, so that if coal is stored in quantity arrangements should be made to take the temperature of the heaps periodically

The danger of the spontaneous ignition and explosion of dust is well known, so that in processes where dust is generated special precautions should be taken for its extraction and bare flames absolutely prohibited In particular, hot water pipes and radiators should be kept free from dust The generation of static electricity should be guarded against or, if unpreventable, the atmosphere should be kept humidified and the machines earthed Inflammable rubbish and waste should be placed in specially constructed bins

Not the least important point is to know what to do in case of fire and who is to do it The responsibility for fire protection should be upon the works manager, who should see that the fire brigade authorities are conversant with the position, organize a fire squad adequate to deal with the situation until the brigade arrives, and ensure that the employees are properly educated in regard to procedure in case of fire Fire instructions should be absolutely clear and practical, including what is to be done to the machinery, windows, doors, gas and electricity supply, etc , should the alarm sound Instruction should also be given in the use of chemical extinguishers, buckets, blankets, first aid, etc

POWER SUPPLY

It is now well established that the economic development of any country or region is directly related to the availability of electrical power Whatever may be the developments in the primary sources of power, the gradual application of atomic energy, the burning of natural gas or oil, the harnessing of more water power or of the tides, the final method of transmission of power must remain by means of electricity

Electrical power supply now presents little difficulty anywhere in Britain largely due to the strategic decentralization of power-using agencies during the second world war Thus, almost invariably, it is most economic to produce power from the regional electricity undertaking Only in such special circumstances as extensive availability of surplus steam resulting from process work could local generation of electricity be considered

Where domestic generation of electricity still exists in Britain, a full economic analysis is called for to justify its continuance This can be readily appreciated when the economy of large scale generation of electricity is understood Only in the largest power plants can the optimum economies be attained and only by linking the operation of such plants on a regional basis can the minimum of stand-by equipment to cope with peak loads be achieved It is the peak load condition which affects economy of generation and if the tariff of a commercial consumer is examined it will usually be found that the price he pays for power is affected substantially by his highest rate of consumption within a given period even though the peak loading is of only brief duration

In remote regions, local generation of power may remain necessary In such cases one of the primary considerations is to ensure adequate water-cooling facilities for the factory power station There must be an accurate forecast of the size and nature of the power load and the degree of continuity involved The site of the power house requires attention with regard to fuel and any ash handling problems and so as to minimize the length of distribution lines This will also minimize steam distribution lines and compressed air lines if they are involved The choice of fuel for the factory power station is a vital consideration and in a changing world economy sometimes something of a gamble In the interest of automatic operation oil-firing is the best engineering solution but this must be balanced by the economic considerations of price stability and availability For small scale generation high-speed compression ignition power units are still most economic and reliable sources of power because the capital cost is low and a higher fuel efficiency is possible

In planning the distribution of electrical power within a factory it is vital to ensure that there is universal availability of each kind of supply at all possible points of consumption Modern practice is to equip each section of a factory building with protected bus-bars which enable any kind of power to be tapped at any point in the manufacturing area

METHODS OF APPLYING POWER TO MACHINES

There are four principal methods, viz, by belt, gearing, silent chain and direct motor drive The individual drive has increased greatly in use, being more flexible and convenient in case rearrangement of the lay-out is desired It gives a better appearance to the shop and facilitates lighting It is essential for machines with various movements driven by more than one motor and where push-button control is desirable

Individual drive should be used where the power demands and the working conditions of a machine differ greatly from nearby ones It also permits independent regulation of machine speeds It involves no fast and loose pulleys, no belt maintenance, no belt slip Individual motors permit dynamic braking and easy reversal, and there is no limitation on speed The motor must, of course, be of sufficient capacity to carry the maximum load of the machine, but full load will not be required for part of the time The grouped drive is therefore frequently more economic, not only in cost of installation and switch control but also in power consumption, as it is most unlikely that the peak loads on all machines will occur together and the larger motor may be more efficient and have a better power factor, especially at light loads Whilst the individual electric drive is very satisfactory in certain instances, advantages are claimed for the grouped drive in capital outlay, running and maintenance costs Objection to grouped drive may be taken that a whole group of machines may be put out of action by a single motor fault and it must be expensive if part of the plant is idle, but this is doubtful unless the idleness is a high percentage, especially if the groups are correctly planned Intelligent grouping takes into account machine power demands, loads, operating functions, and working hours In all cases the possible economies in power must be weighed against any disadvantages in production arrangements The best drive for any particular job can only be selected from a knowledge of all pertinent facts relating to the installation A good factory drive is usually a carefully planned, well-balanced combination of individual and grouped drives

There are a number of economic problems in the choice of an electric motor Price has to be considered against quality and the choice of high efficiency is usually sound economically, as the energy saved thereby may more than repay the cost of the motor A larger machine than is necessary on physical grounds may give advantages owing to higher efficiency The possible economic advantages of under-running require careful investigation, especially where energy is dear or the load-hours high, quite apart from over-specifying to cover possible overloads

Power consumption should be recorded during working periods A suitable division of plant for this purpose will show characteristics in the records any deviation from which means some interference with correct working which is worth investigation

HEATING AND VENTILATING

The economic selection of the heating equipment depends on the same factors as for any other equipment, viz, the balancing of investment costs against operating costs but bearing in mind the comfort and therefore the efficiency of the operatives The greater the period of the year during which the system is in use, the higher the initial investment justified The systems generally employed are pipes and radiators heated by water or steam and unit heaters usually electrically heated If a factory has a supply of low-pressure steam which would otherwise not be utilized, the operating costs of steam-heating the factory are, of course, low On the other hand the use of unit heaters is increasing, as they may be conveniently placed where most needed Electric heaters may be suspended so as to direct a stream of warmed air downwards or placed on the floor and thermostatically controlled, but in any case a continual circulation is developed This prevents a stagnant atmosphere and is useful in drying and dispersing fog or condensate from heat processes

Good air conditions are conducive to health and efficiency An average person in sedentary work exhales about 1,340 cub in of CO_2 per hour, gives off about 400 B Th U of heat, and the lungs and skin give off about 550 grains of water per hour

Bad ventilation results in lower output and quality, increased sickness and accident frequency, and affects labour turnover Comfort is due to a physical condition of the air rather than a chemical one Its cooling power is due to its temperature and velocity of circulation so that the air must be properly introduced and uniformly distributed through the shop The welfare pamphlet on "Ventilation of Factories and Workshops" makes certain recommendations such as that the air must be kept in movement to avoid fatigue, that cool air is better than hot damp air, that there should be some diversion of temperature to avoid monotony and a working temperature of not less than 60° F About 30 to 50 cub ft per workman per minute are required or the air in the shop should be changed about six times per hour, depending on the outside temperature

It is suggested that the relative humidity should be 50 per cent of saturation

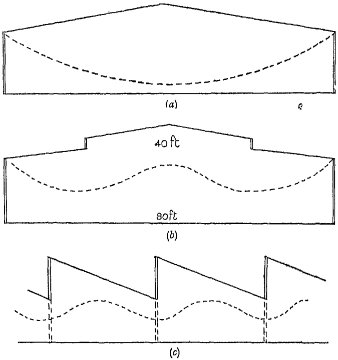
There are two systems of ventilation, viz, natural and forced The former utilizes the normal movements of air currents, warm air leaving at or near the roof In the latter system, mechanical equipment (fans) pull the fresh air into the shop, in some cases after it has been conditioned (filtered, cleaned and humidified), and distribute it where required The quantity of conditioned air desirable varies with the occupation to be carried on in the building Whilst a certain amount of cooling may be obtained by air washing, fully conditioned air is only obtained by refrigeration Frequently a plenum system is employed consisting of a main trunk line and lateral branches or ducts

Contaminated air, dust, odours and fumes must be removed by exhaust systems from, for example, enamelling and spraying rooms, foundries and glass-making, chemical and lead works

ILLUMINATION—NATURAL LIGHTING

Adequate daylighting must be provided for, cloudy days being taken into account

A factory may derive its light from side windows or from the roof or both With lighting from side windows the illumination falls off rapidly towards the centre of the shop, the working space, when lighted from both sides, being roughly three times the height of the window (see Fig 29 (a)) Lighting is improved by increasing the size, especially the height, of windows, which accounts for the fact that in some factories as much as 75 per cent of the wall area consists of glass Whilst good natural lighting is generally required, the all-glass factory is not necessarily the only solution, many processes demand wall surface The introduction of glass bricks may be noted as they are decorative, hygienic, and easy to clean Their light transmission is 75 per cent, and they have good insulating and



SHOP SECTIONS

FIG 29 LIGHT INTENSITY CURVES
(Scale Not Shown)

fire-resistant properties They may also be useful in roof lighting Prismatic glass and Vita glass are usually too expensive for factory use In wide shops the intensity of illumination in the middle is augmented by the use of monitor windows (Fig 29 (*b*)), the best width of the monitor being one-half that of the building The total glass area wide side windows should be about 30 per cent of the floor area

Roof illumination, with the north-facing saw-tooth type of structure (Fig 29 (*c*)) also gives fairly uniform intensity

Care should be taken to see that adequate provision is made for cleaning windows, as they may lose 50 per cent in efficiency from six months' dirt

Even under the best conditions natural daylight can be depended on during only a relatively few months of the year and artificial light is usually required for some part or all of the day

As the natural lighting becomes inadequate a point is reached for which the term "grumble point" has been coined, after which artificial lighting becomes necessary, and the discretion of the shop foreman should be such that the lights are on just prior to reaching the grumble point, and that false economy is not practised by trying to cut down the light bill

ARTIFICIAL LIGHTING

Good artificial lighting in a factory is a cardinal factor in maintaining the normal output during lighting hours Poor lighting imposes a continual physical and mental strain on the operatives, depresses them, and acts adversely on their health

Lighting requirements must be based on the visual demands of the work The misuse of high-intensity lighting is just as bad as insufficient light Special attention should be given to the lighting of stairs and passage ways

Electricity has gradually displaced gas for lighting purposes, but the modern improvements in gas burning, e g use of high-pressure supply, and preheating gas in burners have resulted in a high standard of illumination by gas which is still used for outside lighting

Inadequate lighting is usually disclosed by decreased production rate, spoiled work, higher accident rate, eye-strain, ill-health and consequent higher absence rate

Accidents are caused when operatives are unable to see clearly what they are doing The ability to see an object depends on size, contrast, brightness and time of exposure With low intensities of illumination a relatively long time is required for perception, too long, for example, to prevent the occurrence of an accident As illumination increases the time required for perception is reduced, e g at 10 foot-candles illumination the eye takes only two-thirds of the time to perceive an object that is necessary at 5 foot-candles illumination

Glare or excessive contrast in brightness is a common fault in industrial lighting, especially direct glare It defeats its own object, as the eye cannot take advantage of the illumination provided It reduces seeing power and gives rise to discomfort, headaches and nervous effects More accidents occur through glare than insufficient light

Flickering caused by objects passing the sources of light should be avoided as it causes the eye to tire Where a stroboscopic effect occurs, protective or warning devices should be used

ECONOMIC VALUE OF GOOD LIGHTING

Good lighting means that not only is the intensity of illumination adequate but that the light is correctly applied Poor lighting lowers the speed of working and therefore the output per man, increases the percentage of scrapped work, is a fruitful source of industrial accidents, and undermines the morale of operatives

Exhaustive tests have been made to determine the relationship between intensity of illumination and the speed and accuracy of operatives In one case of detail work efficiency with an intensity of 20 foot-candles was the same as in daylight As an extreme case intensity was reduced to 2 foot-candles, and it was found that output was reduced 25 per cent and the number of errors increased 100 per cent

The true economic value of good illumination is not determined by comparing the improved production with the installation and maintenance costs as all the gains, e g in comfort, cheerfulness and cleanliness, cannot be measured in terms of £ s d Compared with other charges that for lighting is relatively so small that it may be said that good illumination always pays for itself

TYPES OF LIGHTING INSTALLATIONS

The systems usually employed in industrial buildings are—

1 General overhead lighting, which is satisfactory in the majority of cases, is the least costly and maintenance charges are also low No changes are necessary if there is an alteration in lay-out of the plant

2 Localized overhead lighting Fittings are arranged in groups to illuminate large plant or machinery interfering with the general overhead system Rearrangement of plant will, of course, necessitate modification

3 General lighting combined with local lighting This system is required where high intensity of illumination is demanded for fine or detailed work The local lighting is, of course, supplementary to the general system

4 Special lighting problems may arise with unusual plant, in which case it is usually best to seek the advice of an illuminating engineer

When local lighting is necessary the fittings should be mounted on adjustable arms either attached to the machine or standard on telescopic bases

The steps in the design of a lighting system comprise—

(*a*) Decision on the foot-candle illumination required

(*b*) Selection of the most suitable type of fitting

(*c*) Determination of the location, number and mounting height of fittings (*d*) Ascertainment of the size of lamp required to give the illumination

(*e*) Allowance for the room or shop index

(*f*) Allowance for the coefficient of utilization

(*g*) Allowance for the depreciation factor

A good deal of work is required to ascertain standards of good practice for different classes of industrial operations and shops The desirable intensity of illumination varies with the nature and accuracy of the work, fineness of detail, colour of materials handled, and so on The following intensities are recommended for machine shops

Rough Bench and Machine Work	7–10 foot-candles
Medium Bench and Machine Work	11–14 foot-candles
Fine Bench and Machine Work	15–20 foot candles
Extra Fine Bench and Machine Work	25–50 foot-candles

A manager should determine for himself the intensity of illumination on the working plane in his shops by the use, for example, of a light meter, which is an inexpensive, portable, direct-reading instrument If the readings fall below the figures recommended from experience, there is reason to assume that he should take steps to increase the illumination, as even if he has no evidence that it is inadequate, he may obtain an improvement in production, and in comfort of the operatives There is, however, no reason to increase the illumination beyond a certain point dependent on the class of work, as apart from the liability to glare and eyestrain, unnecessary illumination is uneconomic

Having decided whether the lighting is to be direct, indirect or semi-indirect, the following points should be considered in choosing fittings

(*a*) Is the illumination required for sustained vision on flat surfaces on the horizontal or slightly oblique planes?

(*b*) Is the illumination required on vertical planes in addition to horizontal, as for example in machine shops?

(*c*) Direct glare must be avoided

(*d*) Reflected glare must be avoided

(*e*) Where shadows are desirable they must be soft and luminous (*f*) The fittings must be of such a construction that they are easily cleaned, dust-tight and not liable to breakage

The relative importance of the above must be decided for the illumination scheme in hand, e g for a machine shop it is suggested they are in the following order—*c*, *d*, *a*, *b*, *e*, *f*

Many scientifically designed lighting fittings are available for industrial purposes Usually they are robust enough to protect the lamps without special wire guards and they can, if desired, be rendered acid and fume proof

Vitreous-enamelled steel reflectors are generally suitable for general overhead lighting, the dispersive distribution of light giving adequate illumination on both horizontal and vertical planes

For fine assembly shops, drawing offices and so on where a high intensity is required without glare, a diffusive type of fitting with an opal glass bulb surrounding the lamp is recommended Concentrating reflectors may be used when mounted high above the plane of work, e g above travelling cranes Angle reflectors may be employed to augment an overhead system to ensure well-lighted vertical systems

To secure even illumination light fittings must be arranged symmetrically and not too far apart, the spacing depending on the mounting height The lay-out will depend on the position of obstacles such as columns, shafting, etc. The higher the mounting the fewer the fittings required for uniform illumination The distance from a wall to a fitting should be from one-half to one-third of the spacing distance

The size of lamp may be calculated as follows—

Lamp lumens per fitting = foot-candles illumination multiplied by the area to be illuminated per fitting, multiplied by the depreciation factor, and divided by the coefficient of utilization

It should be remembered that for large gas-filled lamps the efficiency—i e lumens—output per watt input, is higher than for smaller lamps and where conditions allow for such lamps, the former should be used, as better illumination is obtained for the current consumed

APPROXIMATE EFFICIENCIES

Lamp	Lumens per watt
Edison's 16 c p lamp, 1880	3
Nernst rare earth filament, 1897	6
Tungsten (vacuum)	8–10
Tungsten (gas-filled)	11–15
Tungsten (gas-filled modern)	20
Discharge tube (mercury)	45
Discharge tube (sodium)	55
Discharge tube (maximum)	70

The expense of an artificial illumination system depends on—

(1) The cost of installation (2) The cost of lamp renewals (3) The cost of the electricity consumed Item 3 is considerably greater than item 2, so that the use of the best and most efficient lamps is economic

5 The room or shop index depends on its size and shape and the height of the lamps above the plane of the work

6 The coefficient of utilization is the proportion of the light produced from the lamps which reaches the plane of the work and varies with the proportions of the room, the colour of the walls, the ceiling and the machines and the type of fitting

The reflectivity of side walls is usually about 50 per cent and of ceilings about 70 per cent, but depends, of course, on the colour

7 The depreciation factor is the allowance made in extra initial illumination to compensate for deterioration due to dirt, dust and ageing, usually about 30 per cent

An organized system of maintenance is essential to prevent deterioration Enclosed fittings may depreciate 20 per cent in two months from dust and dirt, so that all lamps and fittings should be cleaned every four to six weeks Detachable reflectors facilitate this work Maintenance of an outside lighting system is always higher than that of interiors but is important for the prevention of accidents in yards, entrances, etc The roof structure of a factory will generally decide the lay-out of the lighting system, the fittings being mounted on the beams or girders Detailed lighting schemes for different kinds of shops will not be given here, but attention is drawn to the necessity for well lighting the stores, a point frequently neglected and resulting in much loss of time Standard dispersive reflectors down the gangways between the bins are satisfactory in many cases

FACTORY LAY-OUT

The function of a factory is production and in modern factories manufacture must be highly organized and controlled on scientific lines To yield real economies, factories must be designed about the processes they are intended to house, haphazard lay-out is conducive to loss and even danger

The first point then in deciding factory lay-out is the nature of the product, and what and how much is to be manufactured, as it is obvious that the scale of operations may quite possibly modify the general lay-out

The steps in modern factory lay-out may be summarized as follows—

1 Forecast of quantity to be produced.
2 Ascertainment of operations and times
3 Determination of sequence of operations
4 Determination of the equipment required
5 Determination whether to group or place in sequence
6 Compromise between the ideal and economically practicable building, so as to obtain the maximum output per square foot with the best possible working conditions

The initial producing capacity will be fixed by what is reasonable in view of the buying power of the market and the existing supply, but the factory will be planned for rapid enlargement if necessary The lay-out of a plant offers many complex problems for the designer, and will depend on the function for which the plant is intended, the type of industry, the product manufactured, the operations worked, and other factors Factory lay-out must secure unimpaired movement or flow A lay-out which causes

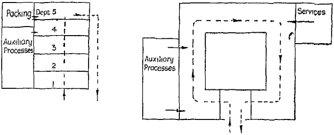


FIG 30 SIMPLE DIRECT-LINE LAY-OUTS

products to retrace their steps in the plant, or to be handled for long distances or an unnecessary number of times, is costly, and a burden to production from the outset This emphasizes the necessity for a direct-line lay-out, i e adequate internal transport for minimum movement of materials, with convenient centres for works stores and auxiliary services

Fig 30 shows two simple direct-line lay-outs with auxiliary services arranged to feed direct into the departments or sections requiring them and the product passing straight through the factory from receipt of raw materials to dispatch of finished goods

A suggestion for a plan of a works making an engineering product such as a motor-car engine is shown in Fig 31 It will be noted that the materials in the course of manufacture move forward continuously in a straight line A foundry is shown, but the question to decide first is whether it will pay, in other words, can castings of the necessary precision be purchased more cheaply outside from a specialized firm? Similar considerations apply to the pattern shop, viz , will it pay to make the patterns required? The provision of good internal siding facilities is essential for the expeditious receipt, handling, and distribution of raw materials, and semi-finished or wholly manufactured

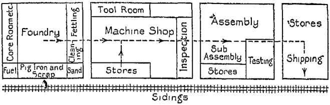
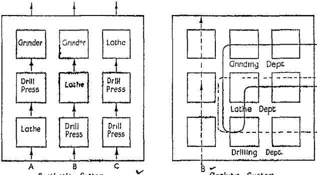


FIG 31 STRAIGHT-LINE LAY-OUT

parts, so that they can be taken direct to the shops where further operations have to be performed on them or to the most conveniently situated store, in order that further handling may be reduced to a minimum

GROUP *v* LINE MACHINE LAY-OUT

The next point to decide on is the system of manufacture to be employed There are two main methods of lay-out the shop method in which similar types of plant are



Synthetic System Analytic System

FIG 32 MACHINE LAY-OUTS

grouped in departments, and the line method of production and assembly There is, however, frequently a combination of the two, involving manufacturing sequences whilst retaining the specialized groups associated with the shop method Is the production equipment to be laid down on the flow or the group system?

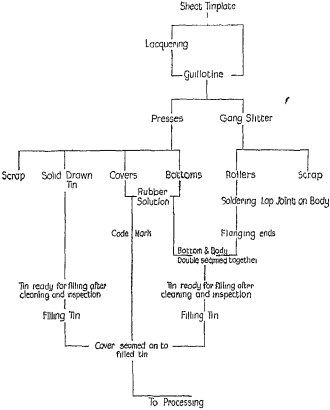

Sheet Tinplate
Lacquering
Guillotine
Presses
Gang Slitter
Scrap
Solid Drawn Tin
Covers
Bottoms
Rollers
Scrap
Rubber Solution
Soldering Lap Joint on Body
Code Mark
Flanging ends
Bottom & Body Double seamed together
Tin ready for filling after cleaning and inspection
Tin ready for filling after cleaning and inspection
Filling Tin
Filling Tin
Cover seamed on to filled tin
To Processing

FIG 33 FLOW SHEET FOR THE MANUFACTURE OF A CAN FOR FOOD PRODUCTS

The synthetic system of manufacture in which processes follow an orderly sequence is undoubtedly the most economic for production on a large scale, but the plant in many engineering firms is still arranged on the group system The latter might be designated an analytic system as products are routed to machine groups in accordance with the operations required, but do not progress in a straightforward flow Intensive production on a grouped lay-out, i e eliminating non-producing time, presents many

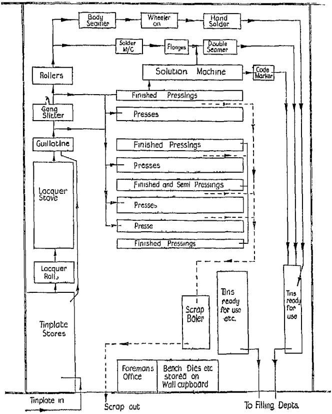


FIG 34 SUGGESTED LAY-OUT FOR FLOW SHEET

difficulties, and nice problems arise as to when it is economic to break up a group system and lay down a special production line

The two systems are simply illustrated in Fig 32, which should be self-explanatory as concerning the manufacture of three products A, B and C in alternative lay-outs

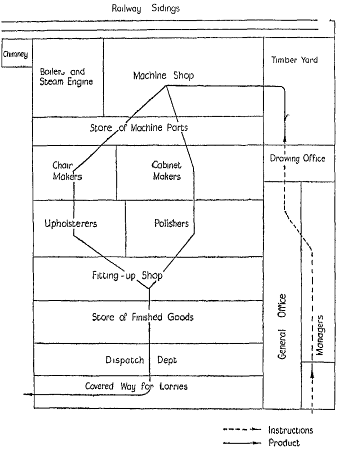


FIG 35 LAY-OUT OF A CHAIR FACTORY

Factory lay-out to-day is a continuous study which influences every phase of manufacturing operation Design and equipment change more frequently than formerly, and the lay-out must change with them

Flow Work Lay-out

Let us consider further the line system in which the lay-out follows the process flow diagram The process

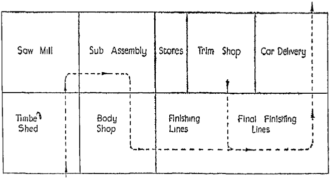


Fig 36 Car Bodywork Factory Lay out

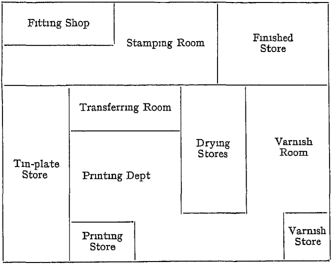


Fig 37 Lay-out for Metal-box Manufacture

engineer will establish the production centres to apply the well-known straight-line principle, making each process a move forward, branching or connecting the flow lines where necessary, balancing the capacities of each stage of production, and using space economically, but with an eye to ease of future expansion The conversion of a flow sheet into a plant lay-out may be illustrated by the diagrams relating to the manufacture of tin cans in a canning factory (Figs 33 and 34) The direct flow and the short moves will be noticed The tinplate is brought in and the scrap removed periodically, but the tins may be passed out continuously on any suitable form of gravity runway

Further to illustrate the straight-line lay-out, diagrams are given referring to a chair factory, a car bodywork factory, and a metal-box factory (Figs 35, 36, and 37)

SUBSEQUENT STEPS

The next feature in lay-out is to make provision for the external and internal transport, including labour aiding and saving devices Movement will be minimized, and adequate transport capacity secured with a view to eliminating accumulation of raw material or finished work in a way to interfere with the producers The next point is to arrange for service centres (stores, inspection, tool-room, test-room, auxiliary services, offices) at the most strategic points and consistent with the optimum utilization of space The choice of the most efficient plant in relation to the projected production is a technical matter and will not be referred to here except to say that productive capacities must be balanced to prevent bottle-necks Production flow is the keynote Accurate scale plans of each shop should be prepared and the positional relationship of the shops indicated The position of entry of the raw material into the shop should be marked on the shop plan and the point where the finished products leave In laying down the position of equipment and arrangement of machines recourse may be had with advantage to the use of floor space templates to scale as illustrated in the accompanying diagrams (Fig 38) This permits the convenient arrangement of plant in the proper sequence, ensures that the floor is not too crowded and the gangways adequate, and establishes in advance conformity with the Factories Acts and by-laws

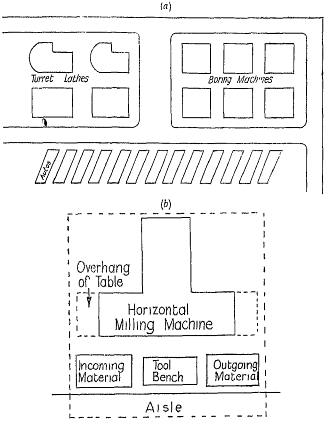


FIG 38 USE OF TEMPLATES IN LAY-OUT
(Scale models of the machines may be made in cardboard)

The fact should not be overlooked that the work may have to stand temporarily by the machine either before processing or when awaiting inspection and benches may be required for tools, so that the pieces of cardboard may usefully be made to cover the area required in servicing the machine Particularly with large machine tools, it is the size of the production centre which is important rather than the plan area of the machine itself (Fig 38 (*b*))

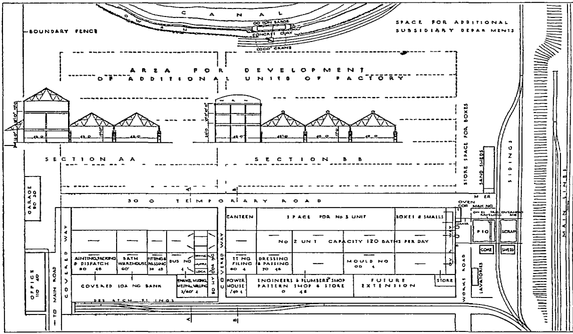
Scale dummies or templates of machines are convenient in studying alternative lay-outs, e g as to whether a line of machines is more suitable in the circumstances than mixed or grouped machines

Consideration will be given to the methods and arrangements for supplying power, water, compressed air, steam, and so on as required by the processes in question The location and arrangement of departments may now receive attention, including choice of single- or multi-storey buildings, wing or bay construction multi-storey buildings may already have been suggested by a desire to use gravity flow

The receiving and dispatching departments are obviously best located on the ground floor Good examples of multi storey lay-outs may be found in the textile industry In worsted yarn plants, for example, the raw material may be blown in on the third storey, carded and fall down chutes to the first storey where it is combed, and fall by gravity again to the ground floor where the short fibres may go one way and the long fibres the other, being elevated to the drawing, twisting, spinning and winding operations

In single-storey buildings use may be made of the unit system, the factory being divided into a number of bays, each a complete unit, which reduces costs by standardization and repetition Fig 39 shows the lay-out of a works on the unit system, each bay being adapted for the continuous production of 120 baths per day, so that merely by multiplying the number of bays the output of the factory can be increased to any desired multiple of 120

In laying out each unit of this factory, the floor space was first calculated for the plant required in the various processes for the stated output, and by dividing by the length of the site the bay width was ascertained The lay-out will be recognized as a good example of straight-line flow, the heavy raw materials which are canal-borne being



By courtesy of Messrs C W Glover & Partners

FIG 39 LAY-OUT OF A BATH FOUNDRY

stored at one end adjacent to the cupolas, and the product passing through the moulding, dressing and fitting departments, across the covered road, to the enamelling and finishing departments The baths pass into the warehouse, from which they are taken, painted, packed and dispatched by either rail or road

With the tendency to line lay-out of machines there may be a danger, however, of a relatively high length-width ratio for bays making it difficult to supervise or to group machines In order to economize floor space alternate high- and low-bay construction may be useful

Adequate provision must obviously be made for economic expansion or the addition of supplementary processes Equipment and processes involving dust and fumes or operations which are hazardous or noisy must be separated from the rest The testing department may be taken as an example of one which must be kept free from noise and vibration Fire hazards and general safety and the provision of ventilation, lighting and heating must receive attention Finally, after consultation between the process engineer and an industrial architect, the lay-out may be completed by suitable buildings

Efficient factory lay-out increases the capacity of a plant of given size, and is the foundation of economical production Within a given floor space the lay-out may be the controlling factor in determining the effectiveness of the manufacturing enterprise

It must be remembered, however, that there is no such thing as a stable ideal lay-out of either buildings or plant, and particularly in rapidly developing industries it is dangerous to plan the lay-out without flexibility in mind One portion of a factory may have to expand without corresponding growth in other portions, but unless each shop can "breathe" comfortably, a patchy lay-out may result and the fundamental plan be upset

Assuming that the most suitable machine equipment has been installed in the most effective sequence, the work must be so planned that every machine is employed and the desired output achieved As a rule, actual production occupies less than half the time taken to complete a given part, and the importance of convenience in handling and rapidity of transport will thus be appreciated

FACTORY INTERNAL TRANSPORT

The great importance of internal transport as a factor influencing factory efficiency needs no emphasis If it is inadequate it causes delays and limits productive capacity, constituting a "hidden" cost of production which in an era of narrow profit margins may have serious effects

The usual manufacturing cycle consists more in moving than making, so that attention should be directed to fitting the internal transport system to the production equipment so that they constitute a single unit By materials being delivered as fast as needed, productive labour is made more effective and the unit cost of production is reduced

The proper order of consideration of the factors governing the lay-out of a new plant is important Materials-handling problems must be studied when planning the equipment and prior to erection of the factory, as internal transport arrangements will influence, if not decide, the size, design and construction of the buildings, and even the site and future development of the plant In continuous manufacture the entire process is built round the materials-handling equipment In an existing plant, the selection of the most efficient internal transport system may increase output, speed up deliveries, decrease the manufacturing cycle and inventories, or in other ways decrease costs of production by smoother and speedier manufacture

Co-ordination is the keynote in lay-out as well as in organization, co-ordination of the handling methods with production equipment and the shipping methods Consideration should be given to containers, skid platforms or special devices improvised to meet the requirements of the process The product itself may have to be designed from the handling point of view, and in all these matters the safety of the operators and the "foolproofness" of the equipment must be borne in mind, especially in view of the large percentage of industrial injuries that are due to falling objects

Many of the problems of mechanical handling are reduced or eliminated by a planned lay-out reducing moves to a minimum and having successive operations next door to each other In any case the transport problem should be considered as a whole, and not as a number of small problems Mechanical handling cannot correct a poor lay-out however badly it is needed to overcome transport shortcomings It should not be used unless the quantity of goods to be transported, their size or nature, the distances covered, the saving of floor space, less likelihood of damage or some other factor justifies the expense and renders mechanical transport cheaper than manual means

TYPES OF MATERIALS-HANDLING EQUIPMENT

Materials-handling systems may be classified into—

(1) lifting and lowering, (2) transporting, (3) a combination of (1) and (2), or alternatively into (1) overhead, (2) floor systems

Mechanical handling is, however, so large a subject as to have acquired a literature of its own and cannot be dealt with here except by a reference to its scope

The mechanisms include—

1 Cranes jib, gantry, overhead travelling, locomotive, wharf

2 Hoists rope, chain, magnet, bucket, skip, drag-lines, winches, car handling

3 Elevators and Conveyors platform, tray, bucket, gravity, including spiral chutes, belt, push-bar, screw, pneumatic

4 Overhead Carriers tramrail, monorail, telpher, cableways

5 Rail Conveyors railways, storage battery, petrol, steam, compressed air, locomotives

6 Trackless Carriers petrol, storage battery, tractors and trailers

7 Coal and Ash Handling Equipment storage and weighing machines

Considerable publicity is given to "conveyorized" handling with the refinements of speed reducers and photo-electric control on account of its elimination of waste motion, but it must be remembered that it is not as yet widely applicable in engineering work except for assembly processes A "conveyorized" foundry is certainly a beautiful example of efficient materials handling, but in many processes it is not the most economic procedure A recent analysis of American handling methods gave the following order—1 Hand trucks 2 Hand lift trucks 3 Overhead cranes 4 Monorails 5 Miscellaneous conveyors 6 Gravity conveyors 7 Belt conveyors 8 Industrial railways 9 Hand labour

SELECTION OF MATERIALS-HANDLING EQUIPMENT

The selection of equipment depends on so many factors that it is impossible to make any recommendations without considering some specific problem These factors include (1) the nature of the commodity handled, (2) the size, shape, weight and fragility of the product, (3) the production rate of the plant or the amount to be handled, (4) the distances to be covered, (5) the sequence of the processes and number of times materials, etc , are handled, (6) the possibility of increased speeds, (7) the type of container, if any, (8) the possibility of future expansion, (9) the location of assembly and testing, also shipping connections, (10) the first cost, (11) the maintenance and depreciation rates, and (12) the availability and cost of unskilled labour

Every type of handling equipment has advantages under certain conditions, so that it is essential to review each method and select the most efficient for the purpose in view and the volume of work involved Choice must be made of the methods which result in the least cost, but this means considerably more than the first cost Apart from investment costs, upkeep and running expenses, provision for flexibility, failure and possible extensions has to be borne in mind It is advisable to choose standard equipment where possible, and it is assumed that the possibilities of gravity feed have been explored before choosing power drive

Emphasis has been placed above on the necessity for continuity of operation and for saving time in transport The best tool for ensuring unidirectional flow, as well as controlling the rate of flow, is, of course, the conveyor With conveyors work can be performed on the product while it is being moved The progressive assembly of gas stoves may be quoted as an example of cost reduction by conveyor work It has been found that when ten or more operatives can be grouped for work, progressive conveyance of work will prove worth while

The speed of a conveyor is supposed to act as a regularizer, but unless each process is time-studied and reduced to an equivalent time throughout the length of the belt, it is not possible to obtain production capacity throughout the whole process By this method any bottle-neck can be widened by the addition of further operatives or by breaking down the bottle-neck process into elements until the production flow of each element is a regular one

A number of forms of conveyor have been devised, working with benches on one side or both, or without benches They consist of belts of rubber, canvas, steel, or other material, or of slats which have the advantage that they can be used as lifts, in fact, progressive handling may vary from simple roller conveyors to elaborate special-purpose plants, such as vibro-conveyors, selective conveyors for depositing goods at a predetermined station, and conveyors for electro-plating and oven or furnace work

Conveying has become a special branch of the science of planning manufacture

The capital and maintenance charges of conveyors are sometimes quoted as lower than for trucks of equal capacity, but for non-continuous work or when the quantity to be moved is insufficient to keep a conveyor working, trucks have a universality of application as well as a possible economy in use There are many designs and constructions of trucks for loading, unloading, tiering, etc , as well as transporting, and the one best adapted to the kind of work in hand should be chosen

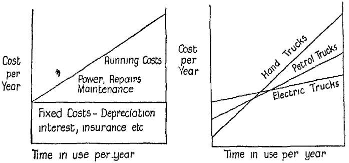


FIG 40 OPERATING COST OF TRUCKS

Where a works consists of a number of buildings, a narrow-gauge railway between and through the shops possesses advantages The use of overhead cranes in shops is too familiar to require further reference.

CHOICE BETWEEN TYPES OF TRUCKS

The operating costs of trucks may be represented as shown in Fig 20

The operating cost may be expressed by a simple formula—

$$y = \alpha + \frac{\beta}{x} + \gamma \frac{x}{s}$$

where α, β, γ are constants,
x is the length of haul and
s is the speed of the truck

$\frac{\beta}{x}$ represents the cost of idling and

$\gamma\frac{x}{s}$ represents the cost of moving

The period in use may decide which type of truck is most economic

In general, the greater the period of use the more likely is the advantage to lie in the various types of trucks in the following order electric truck, petrol truck, hand truck

How soon will an installation pay for itself?

A simple treatment of the economics of a materials-handling equipment is as follows—

Let C be the initial cost

The debit items as regards this investment are—

I = the percentage allowance for interest

M = the percentage allowance for maintenance and repairs

D = the percentage allowance for depreciation

R = the percentage allowance for rates and taxes

S = the yearly cost of power and supplies

The credit items are—

Y = the yearly saving in direct labour cost

Z = the yearly saving in overhead

U = the yearly saving through increased output

The fixed operating cost is—

$$C(I + M + D + R)/100$$

The maximum investment justified is—

$$\frac{Y + Z + U - S}{I + M + D + R} \times \frac{100}{p}$$

(p = the percentage of the year the equipment is used)

The yearly profit from the investment is—

$$(Y + Z + U - S)\,p - C(I + M + D + R)/100$$

and the percentage annual saving is obtained by dividing this by C, from which can be calculated the time required by the installation to pay for itself

COST REDUCTION BY MECHANICAL HANDLING

It has been emphasized above that moving time is idle production time Among the ways in which mechanized internal transport assists in cost reduction, especially when it can be made a pacemaker for the productive machinery, the following may be mentioned—

The period of the production cycle is lessened, output is increased, unit transportation cost is reduced,

Stock holding is reduced to a minimum (examples are known where stock holding has been reduced as much as 70 per cent) and a quicker turnover of invested capital is obtained,

Floor space is conserved, and reorganization, regrouping and concentration of machines facilitated,

A steady flow compels teamwork, time-keeping is mechanized and production control facilitated,

Integrated and synchronized production is possible and limits are removed from production size

WORKS ENGINEERING

The contribution of the works engineering department to the efficiency of a works needs no emphasis If a breakdown occurs production stops and the work of the planning and progress departments is dislocated, the work of the works engineer is thus vital in achieving the production schedule

It has been previously indicated that maintenance is a struggle against deterioration from wear and tear of plant in use Unless plant is kept in efficient condition, the rate of production slows up and increased costs result The work of the plant department cannot guard against obsolescence, but by preserving the fixed assets in good working order it enables them to operate at full load and earn a maximum income with a view to the early establishment of a replacement fund

DUTIES OF WORKS ENGINEER

The duties of the works engineer may vary according to whether he is in a large or a small engineering works, but in any case the closest co-operation with the production departments is involved

This work may be divided as follows—

(*a*) Buildings and grounds He may be concerned with the erection, extension and supervision of buildings, their fire protection, heating, ventilation and illumination, also water supply, drainage and sanitation

(*b*) Power generation and distribution boilers, engines, turbines, motors, wiring, lamps, the supply of gas and compressed air

(*c*) Production machinery its installation and maintenance

(*d*) Service machinery internal transport The plant engineer may be concerned with its design as well as maintenance

(*e*) Safety provisions throughout the plant

The works engineer should, of course, sit on the executive production committee This will ensure that in matters such as the purchase of machinery, for example, full importance will be given to the question of accessibility, a point frequently overlooked by the staff responsible only for output

PLANT INSPECTION AND RECORDS

The duties of the works engineer being preventive rather than corrective, attention is mainly given to the anticipation of distress in machinery To this end a routine of periodic inspection and reports is established Inspection intervals may vary from daily to annually according to the part of the plant in question

The plan of inspection should be fixed beforehand to ensure that it is carried out at the most convenient time and to avoid interruptions of work Planning tables of maintenance work systematize the work, and the dates at which various machines are to be checked are seen at a glance

MACHINE		NUMBER			LOCATION	
Part	Instructions	Date	Date	Date	Date	Date

R = part due for repair
O = take machine out of service owing to its condition

When the time-table indicates that an inspection is necessary, an instruction work card is filled in and issued to the man doing the job

The maintenance engineer will know from experience how long these inspection operations will take and will be able to form an estimate of their cost in advance He will lay out a proper sequence of jobs and the frequency of inspection will also be determined by experience

The inspection book of suitably printed forms indicates each item of plant, the inspection period, what to do, the report, and the instructions issued and performed It will be recognized that these records also have a value in

Type of Machine 50 h p 3-phase motor No 53
Dept Machine Shop Bay No
To be Examined Every Saturday afternoon

Date	Bearings		Bushes	Slip Rings	Armature		Field Windings	Remarks
	Oil Levels	General Condition			Insulation	Pole Clearances		
8/11/56	O K	Fair	2 Renewed	O K	50 Ω	All O K	10 Ω	Watch bearings
8/12/56	Topped up	Pulley end slack	O K	To be smoothed	50 Ω	10/1000 down at pulley end	1 Ω	Change motor next Sat for bearing renewal

connection with any cases that may arise under the Industrial Injuries Act

As regards repairs, either due to breakdown or as a result of the recommendations in the inspector's report, a requisition may be made out indicating what is to be done, with a column for the cause of the breakdown to be filled in later, and other columns for the time spent and materials used, from which the total cost can be found when the repair is completed

These particulars may subsequently be transferred to the reverse of the machine record card, giving the history of the unit on frequency of repairs under such headings as date, time out of service, nature of repair, cost of repair The cost of repairs may be summarized quarterly and annually, and analysis of these data will not only be useful in selecting between different makers of machinery but also form a basis for the repair budget

Thus the cost of keeping the machines in first-rate condition will be controlled and kept at a minimum

A separate record of breakdowns is kept In the event of a breakdown the plant engineer's duty is, of course, to restore the interrupted service at the earliest possible moment so as to reduce idle time to a minimum

A measure of the efficiency of the department is not necessarily its cost, but, in accordance with the above, may be taken as the percentage of repair jobs done in an emergency If the *efficiency of the plant* is estimated as the ratio of the actual productive machine hours to its machine hours capacity, the efficiency of the plant engineer can be taken as the ratio of the actual productive machine hours to the sum of the actual productive machine hours and the idle machine hours due to breakdown

ORGANIZATION OF MAINTENANCE DEPARTMENT

In the organization of the maintenance department there must be a clear definition of responsibility for the work to be done and the results desired A typical organization of a works engineering department is shown in Fig 11

The engineer, mechanics, and workmen must have good qualifications and experience, and be picked for sound work

Name		Number	Week ending		
Date	Job	Department	Hours	s	d
Signed Approved			Total Gross Wages (Maintenance Engineer)		

Job Dept Total Amount Sanctioned Wages		Sanction No Materials	
Week Ending	Wages Paid	Material Used	Progressive Total Cost

FIG 41 REPAIR COST RECORD

and reliability Their remuneration should be somewhat higher than correspondingly qualified men on the production side on account of the need for reliability and the night and week-end work to be expected

Whilst it conduces to efficiency to organize a central maintenance and machine inspection department, the charges should be debited to the departments using the plants and machinery so that they feel the responsibility for the cost of repairs and maintenance

Requests for the services of the department may be oral or written as there is no time to waste in case of an urgent repair Apart from this, however, orders should be made out for the use of the maintenance department's services In the case of routine services, standard costs will have been established, but for such jobs as the installation of new plant estimates must be made and sanctions obtained

When repair jobs are completed the costs are established from the materials used and the time cards of the repair mechanics, and compared with the budgeted or estimated costs (See Fig 41)

BUDGETING FOR MAINTENANCE

The work of the plant department must not only be planned ahead but the results obtained examined periodically It is recommended to have the plant engineer prepare a yearly budget or forward estimate of the expense to keep the factory in running order This budget may be arranged under expense headings of repairs, replacements, improvements and additions or a classification to meet the factory's special conditions The report must, of course, be intelligible to the financial experts as the cost accountant will need to analyse and criticize it Monthly plant conferences should be held at which the maintenance work is reviewed A report should be presented on the work completed in the last month and the programme of jobs to be undertaken during the next month should be tabled for discussion

Reference has been made above to the necessity for co-operation with all departments The production department will, of course, welcome it, as the work aids and sustains the output and lowers production costs The production men appreciate tidiness and cleanliness of the plant and the reduction to a minimum of corrosion and friction losses

The works engineer will naturally co-operate with the Factory Inspector and take a prominent part in the work of the Safety Committee

The works engineer must not be overwhelmed with routine and detailed work but must have time to plan and develop fresh ideas It has been suggested that he should budget for himself and it is assumed that he maintains graphical control of the work and expenditure of his department He should have time to follow the leading technical papers and journals of the engineering institutions and also to visit plant exhibitions This will serve as an insurance against obsolescence of his own plant

PRODUCTION ENGINEERING

The equipment of workshops can only be referred to in general terms, as it depends so largely on the industry in question The productivity of a factory depends so obviously on the equipment that the other factors affecting production, which have been discussed above, are apt to be overlooked or to receive insufficient attention The causes of high costs may be due quite as much to unnecessary handling charges and idle floor space and equipment as to antiquated machinery and methods As a matter of fact, in most shops the actual production operations are carried on more efficiently than the auxiliary ones Apart from the obvious remedy of buying the latest type of machinery, production costs can be reduced by better control, though in two equally well-organized factories the one with the more efficient equipment will, of course, produce the more economically

The amount of equipment necessary in a factory will depend on the quantity of goods that it has been decided to produce, the capacity of the machines, the time required for set-up, the manufacturing methods adopted, the number of shifts per day, and the number of working hours Many more factors besides the actual equipment will affect production and costs, including the location of the machines to permit the flow of work, the provision of adequate space for the effective handling of each machine, the provision of auxiliary equipment and adequate aisles and runways The productivity of the best equipment may be very considerably reduced if the best working conditions are not also provided It depends, also, on the adequacy of the arrangements for storage of both raw materials and finished goods The means of supplying power to the equipment is another important factor Long shafts and belting cause the loss of comparatively large amounts of energy

Plant and equipment expenditure must be laid down on broad lines so as to budget for improvements and additions as well as repairs and replacements Equipment needs should be forecast in view of anticipated developments It is obviously advantageous, under competitive conditions, to keep the equipment ahead of that of rival firms in productiveness

THE SELECTION OF EQUIPMENT

Planning is the chief characteristic of modern production technique It is as essential in the selection of equipment as in works lay-out, in tool engineering as in the analysis of operations and determination of standards of performance The use of equipment is, of course, with the view to reducing labour costs (although wages may be increased) If there are any cases in which hand labour unaided by machinery is cheaper, the purchase of equipment is not, of course, justified Let us consider an instance where the purchase of a machine costing £C is under consideration

Let i be the rate of interest and insurance
d be the rate of depreciation

r be the rate allowed for repairs

P be the annual cost of power

and let it be assumed that the machine works 350 days per year

Then the daily charge on the machine is

$$\frac{C\,(1 + d + r + \qquad\quad) + P}{350}$$

With regard to labour cost let us assume the following—

	Machine Worker	Hand Worker
Daily wage	W	w
Daily output	O	o
Oncost, percentage of wages	X	x
Then manufacturing cost per unit is	$\frac{W + WX}{O}$	$\frac{w + wx}{o}$

For the installation of the machine to be advantageous, $\frac{w + wx}{o}$ must be greater than

$$\frac{W + WX}{O} + \frac{C(1 + d + r + \qquad\quad) + P}{350}$$

This may be illustrated by a simple diagram as follows—

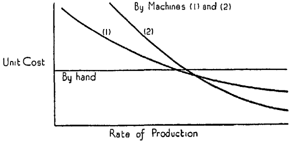


FIG 42 HAND *v* MACHINE PRODUCTION
Effect of quantity on unit cost

This principle is not always fully grasped, viz that there is no other *raison d'être* for machines than the fact that they enable more economical production If they do not enable us to produce more economically than without them, we can with advantage employ hand processes

FACTORS AFFECTING SELECTION

Many factors influence the selection of new equipment besides general design and first cost, such as the type and extent of work, lot sizes and degree of accuracy required We can imagine a works manager, before buying a piece of equipment, asking himself the following questions among others—

Is the capacity sufficient for requirements?

What will be the depreciation of the machine?

What is the power consumption and the other costs of operation?

What type of labour is required to operate it and what is the labour cost?

Is it a safe machine to work?

What floor space will it occupy?

What will be the cost of repairs, and are spare parts readily obtainable?

Does it fit in with the rest of the plant?

What is the risk of obsolescence?

The efficiency of a machine is not a simple but a complex matter It includes, of course, suitability, output, and reliability, but the critical factor is the production cost of work of the required accuracy and quality

In the selection of workshop equipment, the problem is usually one of weighing the cost of the machine and of its operation and maintenance against the value of the work it is capable of turning out Machines are now usually sold with guaranteed production times, which facilitates the works manager's task in this respect

The best machine for a job is not necessarily the most accurate, the most complete, or the most costly A far simpler machine may in the long run be more economical It is not an easy task to pick out from a number of alternatives the machine which will give the greatest return A knowledge of the details of an engineering business is required before one can say what is the best course to pursue Not only is one concerned with the best type of machine for the formulated work, but the numbers and grouping of machines bear on the problem of obtaining the most economical output It is necessary to match the machines, so that they are employed all along the line If their productive power is out of balance, one is faced with the cost of the higher-output machines standing idle To the average works manager a machine is merely a cog in the wheel of production, and when changing the cog the whole wheel is liable to be thrown out of balance if a long-run view is not taken The capacity of a shop is the theoretical capacity multiplied by the efficiency factor Problems arise such as the following Is it more economical *to have* $n + 1$ *machines and one partly idle or* n *machines* and one man partly idle?

Special *v* General-purpose Machines

A recurrent problem is the choice between a general-purpose machine and a special-purpose machine Assuming that the work has been planned in advance and the most suitable machine selected for the job, there is a general tendency to adopt specialized machines, but it must be remembered that the most important item in job costs is overheads, which include depreciation and upkeep, and therefore it must be assumed that sufficient work is foreseen to keep the specialized machine busy If this cannot be anticipated, the general-purpose machine has its chance Apart from the fact that it can be purchased at shorter notice, it is more readily adapted Spare parts can be more readily obtained for standard machines, and tooling is interchangeable A special machine is usually higher in first cost, runs a greater risk of obsolescence and is more costly to maintain, so that the savings in unit manufacturing cost have to be large enough to enable it to pay for itself in a reasonably short time The basis of selection of a machine is fitness for duty, the difficulty is to select the machine of maximum usefulness in the long run For large-scale production the selection of machines can be on the lines of the ideal, for small-scale production it will necessarily be governed by expediency

REPLACEMENT—HOW SOON WILL A MACHINE PAY FOR ITSELF?

Replacement of a machine may be necessitated by a number of events, e g the required output can no longer be obtained, the desired accuracy is no longer possible, lower unit machining costs are essential, a shorter manufacturing cycle is desired to reduce investments in materials, additional repairs or rehabilitation are no longer justified, there have been advances in methods of manufacture or in production materials which the old machine cannot handle economically It is sometimes counselled that whenever an improved design of machine is available it should be bought, but much further analysis is required before the purchase of the new machine can be justified The reduction in manufacturing cost must be compared with the extra charges and the loss on the old machine and an estimate made of the time in which the new machine will pay for itself to see if it is reasonable in all the circumstances within the manager's knowledge

Let C_N be the cost of the new machine
i, d, m be the interest, depreciation and maintenance rates per cent
S_N be the scrap value of the new machine
S_0 be the scrap value of the old machine
C_0 be the book value of the old machine
L_0 be the labour cost with overhead per unit on the old machine

L_N be the labour cost with overhead per unit on the new machine
A_N be the annual output of the new machine
X be the number of years in which the new machine will pay for itself

The annual saving is $A_N (L_O - L_N)$,
therefore in X years this equals $A_N (L_O - L_N) X$

The expense to be met over X years is

$$(C_N - S_N) + (C_O - S_O) + XC_N (1 + d + m + \qquad)$$

Equating the above we have

$$X = \frac{(C_N - S_N) + (C_O - S_O)}{A_N (L_O - L_N) - C_N (1 + d + m + \qquad)}$$

Of course, equations and calculations cannot replace the judgment of the works manager based on practical experience, e g as to the simultaneous performance of operations on some machines but not others, they will provide, however, a guide or a basis for his decision

Common sense is essential in deciding on replacements Even though the saving in labour cost per unit is large, the net saving may not be appreciable Should the annual requirements be limited, it may take a long time for the new machine to pay for itself The manager must guard against spending money to save little or nothing

SELECTING BETWEEN TWO MACHINES

In selecting between two machines, either of which will do the given job from a technical point of view, a comparison will be made between the unit costs of production under the practical conditions of the shop in which they are to be used

Call the machines 1 and 2 and
let C represent first cost
A represent annual output
L represent labour cost per unit
O represent oncost per cent

P represent cost of annual power and supplies
i, d, m represent interest, depreciation, and maintenance rates
X represent unit cost

Then

$$X_1 = \frac{P_1 + (L_1 + L_1O_1)A_1 + C_1(i_1 + d_1 + m_1 + \quad)}{A_1}$$

$$X_2 = \frac{P_2 + (L_2 + L_2O_2)A_2 + C_2(i_2 + d_2 + m_2 + \quad)}{A_2}$$

If both machines are guaranteed as regards output and power consumption, the determination of A and P will be straightforward, but the manager's practical experience will be necessitated in regard to other factors Other things being equal, he will, of course, choose the one with lowest overall costs

This question of selection between two machines may alternatively be considered as follows The cost of production per unit may be divided into two parts (1) a running cost roughly proportionate to the number produced and of which labour cost is an important constituent, (2) a standing or initial cost which is approximately constant whatever the quantity required

Consider two machines M_1 and M_2 of which the first is the more expensive but more efficient, e g the labour cost per unit is not so great as skill has been transferred from the operative to the machine The unit cost of production when using the two machines may be represented by Fig 43

It will be noted that if the output required is large the more expensive but more efficient machine will be the more economical choice

Developments in Machine Tools

There has been a revolution recently in machine tools due to the introduction of improved cutting alloys, requiring increased power and wider range of feeds and speeds

Sometimes the cutting tool has been ahead, sometimes the machine, but the development of tungsten carbide, which has raised cutting speeds to over 1000 feet per minute in some cases, has necessitated increased power, rigidity and strength to take full advantage of the new material This is not the place to go into the advances in machine tool design, e g in balancing, bearings, forced lubrication,

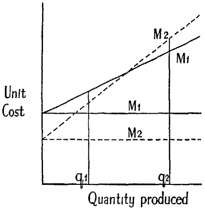


FIG 43 COMPARING UNIT COSTS OF MACHINE PRODUCTION

gearing, single-pulley drive, power-feed motions and quick-return motions, hydraulic control, and so on Suffice it to say that there are many factors other than technical ones in selection, e g convenience of operation, ease of control, with a view to idle-time reduction and increased volume of output In some machine tools hydraulic power for feeds and moving and clamping the work has been developed, but the problem is how far can it with advantage displace the more direct electrical and mechanical powers, or how will the overall cost be affected by adopting it? Are the higher first cost and perhaps upkeep offset by the range of speeds and feeds, freedom from breakdown and lower tool costs? Grinding machines have developed rapidly, e g plunge cutting in cylindrical grinders, and with increasingly finer limits of accuracy of work caused considerable progress in gauging and measuring instruments

MACHINE EFFICIENCY

A machine is bought because it is believed cheaper to produce goods by that machine than any other available at the time The hourly cost of a machine is usually greater than that of an operative, so that the need to control the performance of a machine is of great importance The operating efficiency should therefore be recorded in order to maintain the prescribed figures of capacity and cost

Each item has a definite maximum rate of output which may be regarded as the standard and the efficiency of the machine may be measured as $\frac{\text{Actual Output}}{\text{Possible Output}} \times 100$

A weekly table may be kept as follows—

Machine No	Hours Worked	Possible Output	Actual Output	Efficiency %	Remarks
17	40	4700	3525	75	

The causes of inefficiency must be carefully analysed and may include any of the following—

1 Inefficient production planning
2 Failure of supplies
3 Variable material
4 Absentee labour
5 Inefficient labour
6 Poor operating conditions, lighting, etc
7 Failure of power or service
8 Machine or tool breakdown
9 Inadequate breakdown
10 Inefficient supervision

A bird's-eye view of the effect of machine inefficiency throughout the works may be obtained from a table in the following form—

Department		A	B	C	D	Total
Plant inefficiency (%)		30				
,, in machine hours		200				
Causes	Machine	100				
	Operative	20				
	Material	25				
	Conditions	35				
	Supervision	20				

TOOL ENGINEERING

The great advances in high production output are largely due to increase in efficiency of tools as regards materials, design, and methods of application Whilst interchangeable manufacturing methods were suggested by French gunsmiths from 1717 to 1785, it is only in the comparatively recent period of mass production that tooling methods have been intensively studied and a new branch of engineering has arisen called tool engineering

The contribution of American engineers must not be overlooked in this respect From the time of Eli Whitney, who in 1792 took an order for 10,000 muskets with interchangeable locks, they were largely responsible for the development of interchangeability, in fact, men like North, Colt, Root, Ives, Jerome, Dennison had fully applied the principle by the middle of last century

A tool engineer not only selects machines, but designs jigs, fixtures, special devices and attachments, and arranges set-ups and the tooling up of jobs to drawings The object of tool engineering is, of course, to give lower manufacturing costs with increased speed and accuracy Machining cost includes the constituents of machine cost, tool cost, and labour cost Economic tooling establishes a minimum machining cost in enabling machines to work at maximum capacity

In a firm engaged on continuous production the functions of the tool department will include the following—

1 Anticipate the requirements

2 Design for accuracy or rather the degree of accuracy commercially justifiable The tools must allow the labour available to machine parts to specification at a stipulated price

3 Plan the tool provision so that daily production requirements can be met

4 Determine the cost of tooling-up, involving an indication of the savings over other methods of doing the work

5 Supervise the manufacture of the tools

6 Inspect the tools

7 Supervise the storing of the tools

8 Provide records for the analysis of cost and productivity of the tools

9 Maintain the tools

10 Develop and improve the tools

In continuous production the cost of tools and fixtures is relatively unimportant so long as the expenditure permits the production time to be reduced, time being the chief consideration

In limited production, however, the cost of the tool or fixture has to be justified in each case, with the possible exceptional case where expenditure on a jig avoids the purchasing of another machine to cope with the quantity required

ECONOMICS OF JIGS AND FIXTURES

The economic analysis of the use of jigs and fixtures is really a study of reduction of production costs by the use of accessories

A jig or fixture is a device for holding work so that operations can be performed expeditiously and efficiently

A jig either holds or is held on the work, and contains guides for the various tools

A fixture holds the work while the cutting tools are in operation and, as it has no special arrangements for guiding tools, it has to be firmly held to the machine

Careful design is necessary The first point in laying out a jig is to decide the locating points

A jig should be simple in construction, quick and positive in locating work, fool-proof in loading, rigid with no loose parts, and chip pockets should be avoided as they must be removed quickly Clamping should be rapid and positive without undue effort Mechanical ejecting should be considered

Free access and egress of cutting compound to the jig should be arranged In locating the work small surfaces should be used consistent with support, and supports should be near the point of cutting The operator's safety should be ensured

The chief consideration of production requirements is speed, and the object of jigs and fixtures is to render otherwise difficult and costly operations easier and speedier, yet more accurate In so doing the cost of the jig may be saved

Obviously if the production quantity is small, the justifiable expenditure on a jig is less than if the quantity is large, for quantity production, multiple fixtures and rapid clamping devices may be justified

The solution of the jig problem depends on knowing the cost of production per unit with the existing equipment, and also the unit cost with the use of a jig

If the number of parts ordered is known, it can then be determined whether the saving is sufficient to pay for a jig Alternatively, if the item is in continuous production, the data can be used to determine how soon the jig will pay for itself

The analysis of whether the purchase of a jig is justifiable can be set out in the following simple form

Let N represent yearly requirements in the past
C ,, first cost of the jig
i ,, interest rate per cent
n ,, insurance rate per cent
d ,, depreciation per cent
m ,, repairs and maintenance
S ,, cost of set-up (yearly)
P ,, excess cost of power, supplies (yearly) when jig is used compared with when it is not used

Then total charges yearly $= C(i + n + d + m + \quad) + S + P$

When the jig is in use

Let $L =$ yearly saving in direct labour cost $= N \quad l$
$O =$,, ,, in oncost $= L \quad x = N \quad l \quad x$
$Y =$,, ,, through increased time for other work

Then yearly operating savings $= L + O + Y$

$$= Nl(1 + x) + Y$$

For the jig to justify itself

$$N = \frac{C(i + n + d + m + \quad) + S + P - Y}{l(1 + x)}$$

or

$$C = \frac{Nl(1 + x) + Y - S - P}{(i + n + d + m + \quad)}$$

$$d = \frac{Nl(1 + x) + Y - S - P - C(i + n + m +}{C}$$

The number of years required for the jig to amortise the investment out of earnings $= 1/d$

In general, it may be said to be advisable not to use expensive complicated jigs, simple and inexpensive accessories are as a rule preferable

ELECTRIC DRIVES

Electric driving of machine tools has made great headway, and direct motor drive to heavy machines has been justified by experience Its first advantage is in relation to lay-out as the position of the machine can be selected at will The individual drive is also distinctly favourable from an aesthetic point of view

The trend towards individual drives may, however, be overdone It does not pay to put in a motor for operations required only at long intervals, or for which the mechanical drive is more economical

The power of a motor driving a single machine must be the maximum that may be required at any time, but with a grouped drive one is able to allow for the fact that all the machines never demand their maximum power at the same time The cost per horse-power of a single motor for group drive is considerably less than that of several smaller ones for individual drive In the case of a breakdown, however, the whole line is left standing

HANDLING APPLIANCES

Special attention should be given to means of handling work into and out of machines The latter sometimes appear to be designed without reference to how the work is to be handled, and lack of attention to lifting and moving appliances may risk losing all the time saved from high-speed machinery In view of the necessity for quick handling methods, it has been suggested that the lifting tackle should be incorporated in the machine design

A machine is idle while the operator is loading work, arranging or removing it and, as the desideratum is to keep both the man and the machine employed as fully as possible, special attention must be given to minimizing non-productive time A record should be kept of the actual output of each machine compared with its productive capacity and the reasons for the difference analysed A knowledge of the idle time due to handling the work is the first step towards more efficient results

It is suggested that even greater care should be exercised in the selection of non-productive than in that of productive equipment, as the speed of the former type of equipment often determines the capacity of the plant

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CHAPTER VI

PLANNING PRODUCTION

PRODUCTION involves the organized utilization of natural resources, capital, and labour, and though the relative importance of production factors changes, the most valuable contribution to productive power comes from the mental and physical powers of the people In modern times, owing to the rapidity with which scientific knowledge and invention spread among the industrial nations, the country which shows the greatest aptitude for forethought, planning organization, co-ordination, and co-operation of effort will lead in productiveness, economic progress, and prosperity

Probably the most important factors in production, are to invent and develop, to foresee, to organize, plan and control, to submit existing methods continually to scientific scrutiny, to eliminate waste in the services of men and machines

PRODUCTION FOR A MARKET

In first considering the more general aspects of production, we are concerned with problems of manufacture at a cost which will meet the ruling market price and leave us with a margin Analysis must begin with the customer and be developed backwards The firms which survive and prosper are those which keep in touch with public demand and other trends, and adjust their costs of production to meet the market

In the case of some patented articles, selling prices may have no reference to the cost of production, but the exploitation of a monopoly position is always a two-edged sword—the law of substitution is at work and sooner or later means of circumvention will be found and bring back the problem to one of all-round efficiency in production

In mechanics, efficiency is measured by the output of work divided by the input of energy If we consider a factory as a machine, then the economic efficiency may, for the purpose of comparison, be considered as the selling price of the products divided by the total cost of production The analogy, however, must not be pressed too far The former ratio is always less than one, but the efficiency ratio of a factory must, over a period, be greater than one or production will cease The term "total cost" has been used because it is rare that operating costs cannot be reduced by installing more or better machinery, but the quantity of products that can be absorbed by the market may not be large enough to justify the expenditure The amount of business expected is always the controlling factor in production

The manufacturer must not, however, be hypnotized by mere volume of turnover In seeking mass production, sight must not be lost of profits There is such a thing—as the Americans discovered—as profitless prosperity Over-expansion has ruined businesses It is more important to ascertain whether the plant is concentrating on the right product in the given circumstances, and whether the output is a maximum per £1 invested in plant and employees' wages, than whether the mere physical volume of production could not be increased

Many nice production problems arise in connection with goods in seasonal demand, involving a balancing of alternatives such as temporary closing-down of the plant, manufacture for stock, the development of new uses, making other articles during slack periods or cultivating foreign markets Such a situation calls for the highest business ability to organize production to give maximum long-run profits

PRODUCTION EFFICIENCY

The degree of mechanization of industry is, from one point of view, an index of the industrial progress of a nation The efficiency of labour depends on machinery which increases the volume of output per worker without fatigue and lowers the unit cost, which is of special importance where wages are high A more uniform product is made and at a predicted cost of manufacture

A new type of engineer has arisen called a production engineer, having a sense of the economic process of production which he considers in relation to revenue from expenditure He starts with the most economic method of production and lays down plant suitable for the purposes in view, but which is adaptable, with straight-line paths of progress of the product involving minimum transport times from machine to machine or department to department He sees that materials are supplied to the workshops to keep pace with production, that the machines are fully employed and that the work is not only planned but controlled He gives proper attention to design, standardizing the product and number of types, makes adequate use of jigs and other production auxiliaries, applies time study rationally to fix work speeds, and builds up an organization to operate without waste of material, power or time

Efficient production involves the economic use of materials, men, machinery, and methods It should be noted that in a modern factory all are specialists more or less, and production takes place by the co-ordination of specialists The engagement and training of labour, the placing in jobs and the inculcation of team spirit are, therefore, of the utmost importance to the management to ensure a steady flow of production of the magnitude budgeted for It should be remembered that the maximum individual productivity is attained when a workman is given the highest class of work within his capacity Productivity is stimulated by arranging for the worker to have a definite amount of work to accomplish in a given time, and providing a wage incentive for him to maintain his maximum

Efficiency in production can only be considered in relation to a given type or scale of production, for example, an efficient procedure in large-scale production might be impracticable in small-scale production, and between the two extremes arise problems of great diversity and complexity in which the choice of the most efficient procedure may be largely a matter of experience

JOBBING PRODUCTION

Jobbing production is the traditional form, dating from the early days of the factory system It consists of small-scale production to meet customers' individual requirements Jobbing production is carried on in small factories and is suited for varied work, products of special design and experimental models It possesses considerable elasticity in operation and is capable of technical economies, if not commercial and financial ones Continual thought must be given to the development of cheaper manipulative processes, and thus the jobbing shop obviously forms a good training ground for managerial positions as regards technical knowledge and experience To evaluate correct estimates for work to be done, it is necessary to possess accurate knowledge of what each department or machine can do Considerable importance attaches to the skill and ingenuity of the foreman, and the workmen must possess great manipulative ability

BATCH OR QUANTITY PRODUCTION

This is the commonest type of production in this country, representative of the work of probably three-quarters of the engineering firms This is understandable from the British demand for individuality combined with a diversified foreign demand Some of the most intricate problems in production and management are involved in striking an economic balance in batch production The most economic batch size is determined by sales demand, delivery, and stock requirements—having always a supply on hand, but not an excessive stock Mass production may be introduced for components, combined with high quality and diversity of finished products

The optimum lot size depends not only on the cost of manufacturing but the interest charge on the money invested in the goods and the cost of storing them until sold (See Fig 44) The larger the turnover and cost of manufacturing set-up and the lower the cost per part and the cost of storage, the bigger the lot size will be In other words, if material cost is high the economic production quantity will be small, if labour cost is high and the operation long, it will be small, if the setting-up cost is high, large batches will be economic

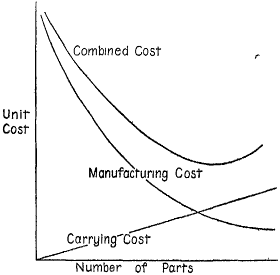


FIG 44 OPTIMUM LOT SIZE

To determine the manufacturing lot size for minimum total cost—

Let x = lot size for minimum cost

M = average monthly requirements of the part

K = cost per part (material, labour, overhead)

U = cost of set-up plus clerical work

I = annual rate of interest, depreciation and insurance

O = minimum quantity in finished stores when new lot is started

C = storage cost per part per year

y = total cost of monthly supply M

The manufacturing cost per part is

$$K + \frac{U}{x} \tag{1}$$

As the quantity in stock varies from O to O + x the average is $O + \frac{x}{2}$

The average investment in finished stock is

$$\left(O + \frac{x}{2}\right)\left(K + \frac{U}{x}\right)$$

and the average charge for interest is

$$\left(O + \frac{x}{2}\right)\left(K + \frac{U}{x}\right)I \tag{2}$$

The monthly storage charge is

$$\frac{C}{12}\left(O + \frac{x}{2}\right) \tag{3}$$

Thus

$$y = M\left(K + \frac{U}{x}\right) + \left(O + \frac{x}{2}\right)\left(K + \frac{U}{x}\right)\frac{I}{12} + \frac{C}{12}\left(O + \frac{x}{2}\right) \tag{4}$$

Now if y is a minimum $\frac{dy}{dx} = 0$

Expanding (4)

$$y = MK + \frac{MU}{x} + \frac{OKI}{12} + \frac{KIx}{24} + \frac{UOI}{12x} + \frac{UI}{24} + \frac{Cx}{24} + \frac{CO}{12}$$

$$\frac{dy}{dx} = -\frac{MU}{x^2} + \frac{KI}{24} - \frac{UOI}{12x^2} + \frac{C}{24} = 0$$

$$\frac{12MU + UOI}{12x^2} = \frac{KI + C}{24}$$

$$x = \sqrt{\frac{24MU + 2UOI}{KI + C}}$$

If the storage charge is small and O is neglected

$$x = \sqrt{\frac{24MU}{KI}}$$

Another method of determining optimum lot size is as follows—

Let x = the number of lots made per year

I = the interest on total raw material cost for a year

S = setting-up cost

O = output required divided by the capacity of the plant

C = cost of finished article divided by cost of raw materials

K = a constant charge on output due to labour storage and all overhead charges

The set-up cost on the total output = Sx

Interest chargeable on material $= \frac{I}{2x}\ O$

Interest chargeable on finished article in storage $= \frac{IC}{2x}\left(1 - O\right)$

Then total cost T

$$= K + Sx + \frac{I}{2x}(O + C - OC)$$

$$\frac{dT}{dx} = S - \frac{I}{2x^2}(O + C - OC)$$

Now if T is a minimum $\frac{dT}{dx} = 0$

and $$x = \sqrt{\frac{I}{S}\left(\frac{O + C - OC}{2}\right)}$$

The following may be taken as an example of this method.

Let the production capacity in a factory of a given article be 100,000 per annum and the sales 20,000 articles per year Suppose further that

the value of the finished article is £1
the value of the material in it is 4s
the labour cost (including oncosts) per article is L
the interest rate is 6 per cent
the cost of set-up is £60

In the following table (Fig 45) the total cost of manufacturing 20,000 articles per annum is worked out if made in 1, 2, 3, 4 and 6 lots respectively, the time to manufacture being $\frac{1}{5}$th of a year in each case

It will be seen that under the conditions postulated it would be most economic to make the annual output in three lots

Mass Production

Mass production means continuous production with no lost time The aim of the production man is to eliminate non-producing time In mass production, parts are made at the rate required for assembly It involves a specially planned factory lay-out with the use of a good deal of one-purpose machinery and frequently of expensive jigs and fixtures Processing and assembling are timed carefully, sometimes to a fraction of a second Inspection plays an important role Continuous production involves minute

COST OF 20,000 ARTICLES PER YEAR

Cost Items	Number of Manufacturing Lots				
	1	2	3	4	6
Labour Cost	20 000 L (say £250)	20 000 L (£250)	20 000 L (£250)	20 000 L (£250)	20 000 L (£250)
Set-up Cost	£60	£120	£180	£240	£360
Interest on Raw Material	($\frac{1}{2}$ × $\frac{1}{5}$ × 20 000 × £$\frac{1}{5}$ × 6%) = £24	£12	£8	£6	£4
Interest on Stock-in-hand	($\frac{2}{5}$ × 20,000 × £1 × 6%) = £480	£240	£160	£120	£80
Total Cost	£814	£622	£598	£616	£694

Fig 45 Calculation Indicating Optimum Lot Size

(The student is advised to plot the unit cost in comparison with Fig 44) subdivision and specialization of operations and machinery, and the utilization of specialists

Its principal advantage is low unit manufacturing costs from simplified operations and the increased skill of specialized workers Other savings arise from lower cost of storage, owing to the maintenance of minimum stocks and simplified production control Owing to the careful forethought and planning required, improved quality may well accompany increased production, and waste is reduced in many directions

It must not be thought that mass production is of recent origin Richard Arkwright, who was born more than 200 years ago, was probably the first to appreciate fully the economic principles of machine production in the mass sense In 1806 Brunel had a plant for the manufacture of pulley blocks at the rate of 100,000 a year and by the specialization of machines each performing a set of operations, ten unskilled men produced as many blocks as 110 skilled men previously Early this century mass production was common practice in the textile industry and in the manufacture of bicycles, watches, clocks, sewing machines, lawn mowers and typewriters In modern times, however, its scope has been considerably extended in various branches of engineering

Mass production is, of course, impossible in the absence of large markets absorbing standard goods On the other hand, it has introduced a new principle into marketing of supply creating demand A good deal depends, however, on the psychology of the buying public

The disadvantages urged against mass production include inflexibility of the specialized plant and the costliness of its replacement, sterilization of design and the loss involved during a period of change-over

Mass production must be distinguished from interchangeability which means that corresponding parts are interchangeable in any of the machines made, but is independent of the quantity As long ago as 1792 Eli Whitney made ten thousand muskets with interchangeable locks Interchangeability was dependent on the development of limit gauges

The introduction of mass-production methods involves the following steps—

1 Analysis of the various stages of manufacture, indicating the operations and types of machine required

2 Timing the operations

3 Determining how many machines will be required for the planned output and what load on them is expected

4 Synchronizing the operations

5 Planning the shop lay-out and deciding in the given circumstances whether to keep together machines of the same type or to distribute them according to the sequence of operations

In general, the labour required in a mass-production shop *is not* highly skilled except in so far as *it* consists of skilled machine-minders

The difference between jobbing production and mass production may be illustrated by contrasting making with manufacturing In the former small quantities of diverse products are made by workshop methods on standard machines (centre lathes, drills) with no special lay-out The men are usually skilled and paid on a time basis

In mass production large quantities of a small number of standardized parts are produced during long runs of special machines (capstans, automatics, multiple-spindle drills, milling machines, shapers, grinders) Jigs, fixtures, dies and pattern plates are widely used The lay-out minimizes movement of work Inspection by limit gauges is frequent Production is synchronized to meet conveyor speeds The labour is semi-skilled and is usually on some form of premium bonus payment

The differences are obvious when considering how one or two gear wheels or connecting rods would be made as compared with large numbers of such parts Other examples will at once suggest themselves, e g one flanged and dished end compared with manufacturing a lot of (say) 500, and one lever arm compared with the mass production of the same part

Mass production yields spectacular results and meets with a good deal of publicity, far more in fact than in proportion to the amount of production that is carried out by this method The reports of H M Inspector of Factories indicate that only about 8 per cent of factories in the country employ over 100 workers, though, in this small proportion, two-thirds of the workers recorded are employed On the other hand, heavy engineering and shipbuilding are the industries in which large-scale production has advanced most rapidly with over 50 per cent of the workers employed in such industries, followed by the metal trades with nearly 50 per cent of the workers employed, and light engineering trades next in proportion

There is, in fact, evident a general tendency towards specialization of men and machines and progressive assembly of products, which partially accounts for the diminution in numbers of all-round machinists and engineers

PLANNING

As the object of the manufacturer is to produce the stipulated quality at the lowest cost, and other things are subservient to this, it is necessary that he should be clear from the start on what he is going to do, and the justification of planning is the final economy which results

Planning is simply looking ahead, the predetermination of future achievement in time, quality and price, analysing all the problems likely to arise in manufacture, and figuring ways and means of achieving efficiency Every human enterprise postulates a plan, and the success of its execution depends on the selection of suitable persons who utilize the best instruments and materials for the purpose No plan can be formed without imagination and foresight, and no body of men can be taught to co-operate in its execution without efficient leadership Moreover one push may be worth a good many tugs It was for this reason that the personal qualities of industrial and business managers were stressed in Book I Team-work is essential, which means that the members of the organization must have faith in the planning methods

Planning is a specialized function of management involving an intimate practical knowledge of the industry, and aiming at a technique which will accurately control every phase of manufacture It involves the establishment in detail of what is going to be done before any work is started With regard to a new factory, the site, output, most economic size of unit, and capital expenditure must first be settled The facilities for receiving and shipping and internal transport must be planned, and the plant designed according to the needs of economic production An essential feature is that the ground-work of production is balanced, with no weak links or choke points to cause delay or shortage, and with facilities for adaptation and expansion The planners may then turn to a detailed analysis of manufacturing methods, the minimum quantity to be made, the liquidation of tools, and so on The reason for the insistence on planning is its final economy and the more accurate costing which results

WORK OF THE PLANNING DEPARTMENT

Production planning amounts to systematization with a view to increasing output without speeding up the operatives The word planning is subject to two definitions—the planning of all operations of production and the planning of the order of production The essentials of planning are, however, fairly well established as the outcome of experience and analysis The design and specifications being worked out, the operation cards and times are established, the tools, jigs and methods fixed, and the sequence of processes routed through the plant The lines of production flow are laid down, and, from the known operation times, a schedule of work is formulated and a time chart established which sets a rate of accomplishment for everyone concerned The procedure for initiating work is laid down and arrangements made for supplying the workmen in advance with the materials, tools and instructions required, for the movement of work, and for the tracing of progress by reports or records Planned schedules are made visible by the use of dispatch charts or boards

It is apparent that planning depends on a knowledge of the capacity of departments to determine the total amount of work that may be undertaken as well as the speed of its throughput Summarizing the constituents of production planning we have—

1 Planning the designs
2 Planning the quality and quantity of material
3 Planning the operations in correct sequence, deciding the methods to be adopted to make each part from start to finish This includes job lay-outs, job specifications, operation instructions with times and grade of labour required
4 Planning the tools, jigs and fixtures
5 Planning the routes or sequence of operations
6 Planning the internal transportation
7 Planning the inspection at strategic points
8 Planning the assembly
9 Planning the schedules, preferably so that the working plan can be seen at a glance This gives a preview of what the position will be at any time till completion

Point 3 may be considered in a little more detail The operation lay-out states the name of the parts and the operations in detail, i e the type of machine, its number or class, the type of tool required, and the time allowed for each operation

The operations are listed in an operation list, and from the operation lay-out the total time required for each class of operation in the manufacture of the various parts is added up This gives the load on the machines and how many machines are required, as illustrated in the following table—

Part No Sets per Week

Component	A	B	C	D	Total Hours
Quantity	100	200			
Drilling Mcs	37				
Milling Mcs	18	20			
Planing Mcs	50				
C Lathes		32	40		
Capstans		72			
Boring Mc					
Grinding Mcs			20		

The total number of hours divided by 47 (if a day shift only is worked) gives the number of machines

If synchronization for assembly is required, the production times must be made equal for each class of part In making this adjustment the planner has available a number of procedures, e g —

1 One machine may be used for more than one operation
2 The same tool may be used on different operations
3 Several machines may be used on one operation
4 Machines may be used with two or more tools alternately

The operation lay-out can then be revised so that the total times for making each part will be approximately equal

Finally the plant lay-out can be adjusted to give the shortest possible moves

Under points 3 and 4, if there is a separate tool design office, co-operation between the process planner and tool engineer is essential to see if the sequence of operations is most satisfactory for tooling purposes The tool engineer may sometimes be able to find a re-arrangement which will effect a saving in tool cost, whilst ensuring the required accuracy of product

The planning of industrial activities is not only aimed at producing a given product at the lowest possible overall cost, but the planning must not be too costly in itself There is no one best way, and every system has its bogy of overhead expenses, each plant must work out its best procedure according to local conditions In some plants all the operations are planned in a central office, in others the departments do a great deal of their planning themselves The differences work out something as follows—

	Centralized Office	Departmental Planning
Product analysis	Office determines the best way of production	Foremen decide how to perform the operations
Machine analysis	Office analyses equipment and decides which to use	A plant list is kept, but no equipment analysis made
Flow of work	Office decides the operation sequence	Foreman decides which machine to operate
Rate fixing	Time of each operation settled	There may be a rate fixing department, otherwise the foreman settles the time
Progress work	Progressing from main control board	Foremen progress operations themselves

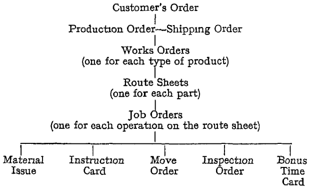
Generally speaking, for the larger type of works and where there is a tendency to continuous production, centralized planning is the more efficient, but it is also essential in large repair shops Even in small works money will be saved by planning jobs stage by stage Otherwise there is loss on production, and if a repeat order comes along there is no record of how the job was done

Care must be taken that centralized planning does not take away interest from production personnel Planning is concerned with production flow and co-ordination and with a balanced sense of proportion will not spend time knocking off seconds in production if hours are being wasted in transporting

Planning permits management by the principle of exceptions, in other words, it is only the departures from the planned production which require the attention of the executives

PROCEDURE ON RECEIPT OF ORDER

On receipt of an order by the sales department, how is the machinery of production set in motion? The procedure will vary with the organization of the works, but complete information of the customer's order must be issued to the manufacturing and accounting departments The sales office will issue a production order to the production department, where works orders will be made out after careful analysis of the requirements and sent to the departments concerned with the manufacture in accordance with the schedule of work



The planning department will fit the work into the routine, indicating a routing for manufacture The works orders, although authorizing manufacture, may not give sufficiently detailed information for it to proceed Job specifications are necessary for the foreman to know exactly what he is to do We have seen in our consideration of the role of the drawing office that it can render valuable assistance at this stage, by issuing blue prints and detailed lists covering the various components Sometimes instruction sheets contain the requisite information for the foreman

Order No	Machine
Job No	Man No
Description	
Job Started	Man's Rate
Job Finished	Labour Cost
Hours	Overhead
Next Operation	Total Cost

FIG 46 JOB CARD FOR SMALL SHOP

The various job orders will be issued by the progress department, but this must not be done before the necessary materials are available If they are not in the store they must be ordered from outside sources, or, as in the case of castings, from the foundry Job cards as used in connection with a time recorder may be issued to enable the actual times to be recorded The job card is written up and issued by the job clerk against the return of a completed card, so that an operator has only one job at a time A job card for a small shop is shown in Fig 46 Payment of workers is made against the job card particulars

Emergency or rush orders should be put through on job cards of a distinguishing colour

There are differences of procedure according to whether the factory is working to definite sales orders, when the job lay-out may become intricate, or to the manufacture of standardized products, when the job lay-out is standardized and production continuous

Job No Z/O 1234
(50 Gross ½ oz Zinc Ointment Lids, A B & Co)

Operation	Operator's No	Machine No	Monday		Tuesday			Total Hours	Rate	Wages
			On	Off	On	Off				
Stamping										
Beading										
Turning in										
Counting										
Packing										

FIG 47 JOB ORDER SUMMARY

The analysis of a job and classification of its components

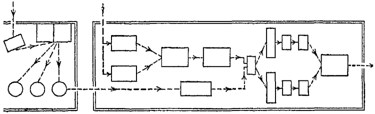


FIG 48 DIAGRAMMATIC CHART OF ROUTE THROUGH A STRAIGHT-LINE LAY-OUT

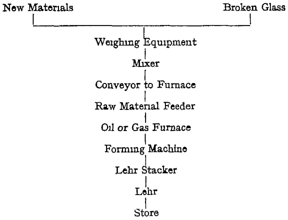
indicate the grade of labour to employ Job cards when completed may constitute their own register if kept in envelopes, but for job-costing purposes they may be summarized in a Job Order Register

ROUTING PRODUCTION

Planning of production would yield incomplete results if it did not include routing, in fact, as we have seen, planning includes not only what is to be produced, but also where Not only must all the operations necessary to transform the raw material into finished parts be determined, but the sequence of operations and the path of the work must be laid down, that is, where each operation is to be performed as shown in Fig 48 Routing systems may vary from extreme simplicity to great complexity, but the fundamental principles remain the same, and the product must flow on continuously with no retracing of steps or unnecessary handling The more highly standardized the product, the more straightforward the routing is likely to be

A route sheet showing the sequence in the manufacture of glass bottles is as follows—

GLASS BOTTLE FLOW SHEET



Other examples of flow sheets in continuous-production processes are the nickel production route sheet issued by the Mond Nickel Company Ltd and the series of flow sheets for many manufacturing industries issued by "The Mechanical World"

It has frequently happened that a study of the path of the product has resulted in a considerable improvement in the lay-out of the shop or works The planning department may be assumed to have provided the best possible equipment and the best possible methods of manufacture, but the capacity of the machines and the time required will have to be determined before routing can be carried on intelligently, so that there are no pauses or congestion in production In this connection the time element is vital if the plant is to work at full capacity

In flow and synchronization of production a knowledge of machine capacities is vital Some very nice problems may arise in an engineering works as to whether it is more economic to retain machine grouping on account of ease of control or to arrange a special line of machines with a simple straight-line route

Part No Symbol Lot Size Drawing No

Operation No	Shop	Machine	Jigs, Fixtures Required	Set Up	Time per Piece	Time per Lot	Labour Rate
1							
2							
3							
4							
5							
6							

Fig 49 Route Card

Route cards set forth graphically the materials used, and their progress from machine operation to machine operation In addition to showing the progress of the work through the shop, they may indicate the percentage allowance for spoilage so that the exact amount of material required may be provided Sometimes the most economical lot size is also stated Route cards usually contain the following columns of particulars the nature of the operation and its number, the machine number, the grade of labour to be employed, the jigs, fixtures and tool numbers for the operation, the time allowance for setting the machine, and the time allowed for the operation itself In some shops a record of the sequence of operations is provided in the form of an operation sheet as illustrated on page 202

PRODUCTION SCHEDULE

The time factor is of vital importance in production Plans must, therefore, be based on definite time-tables If a works is not producing to a time scale there is no means of measuring the efficiency of the machines or men

To secure a smooth continuous flow of production it is necessary not only to trace the path of the work, but to synchronize processes and so avoid a shortage or pressure of work in one particular section of the equipment Particularly is this the case if the finished product of one set of machines is the raw material of another, or in assembly operations utilizing the products of different departments, together with certain components purchased complete from outside firms In other words, production must be balanced and the plant operated as a unit

This synchronization of processes is ensured by the scheduling of production From a knowledge of the operation times in the various shops, the purchase time of raw materials and finished components, the time required for assembly, and so on, the various processes are put in train so that the product in the required form will be delivered as and when needed up to the stage when the finished product is ready for shipment This scheduling involves the co-ordination of outside purchases, machine operations and assemblies so that from a knowledge of delivery times and manufacturing and assembly times a business calendar may be drawn up indicating the dates at which production reaches the specified stages The functioning of a works depends on correct timing, and means must be devised for ensuring that the specified times and dates will be adhered to We shall return to this question of the operation of the schedule—or, as it is sometimes called, dispatching—in Chapter VII

ECONOMIC SELECTION OF MATERIALS

The economic selection of materials depends on the first cost, the ready availability and the cost of fabricating or working up Only a complete analysis will reveal whether one kind of material or another is more economical

An example of the balancing of the first cost against the cost of machining may be taken from the choice between brass and steel for a given component, assuming that either metal meets practical requirements

Using the Following Symbols	Brass Bar	Cold Rolled Steel
Cost per lb	C_B	C_S
Scrap value per lb	P_B	P_S
Weight of component	$1\ 08\ W_S$	W_S
Weight of scrap per component	$\frac{1\ 08\ W_S}{n}$	$\frac{W_S}{n}$
Output per machine-hour	O_1	O_S
Wages per machine-hour	L	L
Overhead per machine-hour	Lx	Lx
Then we have		
Metal cost per component	$1\ 08 W_S\left(C_B - \frac{P_B}{n}\right)$	$W_S\left(C_S - \frac{P_S}{n}\right)$
Manufacturing cost per component	$\frac{L(1 + x)}{O_B}$	$\frac{L(1 + x)}{O_S}$

Extra cost of brass per component

$$= W_S\left[1\ 08\left(C_B - \frac{P_B}{n}\right) - C_S + \frac{P_S}{n}\right]$$

$$= E$$

Extra cost to machine a steel component

$$= L\,(1 + x)\left(\frac{1}{O_S} - \frac{1}{O_B}\right)$$

If we equate these costs and solve for the output of brass components

$$O_B = \frac{O_S L(1 + x)}{L(1 + x) - EO_S}$$

This is the hourly output of brass components which is necessary to balance the extra cost of materials If the actual output is greater, it will pay to turn over to the dearer material

Other examples which may arise out of the necessity to choose between materials are the use of steel or a light alloy and the use of a metal or a moulded material such as bakelite The acid test is, of course, will the change of material yield an overall saving?

Similar economic problems arise in making a choice between the various forms in which the material may be bought before machining operations are commenced, as,

Using the Following Symbols	Castings	Forgings
Weight of component	W	$f\ W$
Cost per lb	C_0	C_F
Weight of turnings	PW	$p\ f\ W$
Scrap value per lb	V	V
Cost per component	$WC_0 - PWV$	$fWC_F - pf\ WV$
Number in a lot	n	N
Extra cost of dies over pattern		E_1
Interest and insurance rate per cent	I	
Storage charge per year	S	
Number of years over which initial charges must be spread	D	
Number of components used in this time	X	

for example, between forgings and castings, ordinary castings and die castings, castings and pressed metal components The first-mentioned may be taken as an illustration It is obvious that the forgings will have to be purchased in larger lots than castings in order to have an economic run once the dies are set up, and this will make the carrying charges higher

The extra metal cost per casting is

$$W\ (C_0 - PV - fC_F + fpV) = E_2$$

The total carrying charge per casting is determined as follows—

The fraction of a year required to use a lot is $\frac{nD}{X}$

Therefore insurance charge per piece is $\frac{WC_0\ I\ nD}{2X}$

and the storage charge $\frac{SnD}{2X}$

Therefore the total is $\frac{nD}{2X}\ (WC_0I + S)$

Similarly for a forging the total carrying charge is

$$\frac{ND}{2X}\ (fWC_FI + S)$$

So that the extra carrying charge on a forging is

$$\frac{D}{2X}\ [N(fWC_FI + S) - n(WC_0I + S)] = \frac{E_3}{X}$$

and the extra initial expense on a forging is $\frac{E_1}{X}$

If we equate the extra metal cost per casting to the sum of the extra charges per forging

$$E_2 = \frac{E_1}{X} + \frac{E_3}{X}$$

or

$$X = \frac{E_1 + E_3}{E_2}$$

so that unless a greater number than this is consumed in D years, it will not pay to change over to forgings

It will be noted that we have assumed in the above that the expense of machining a casting or a forging is the same, but, as more metal generally has to be removed from the former, this factor may have to be included

If, however, the extra machining cost per casting is called E_4 we can re-state the above equation as follows—

$$X = \frac{E_1 + E_3}{E_2 + E_4}$$

ECONOMIC USE OF MATERIALS

Industrial waste is incidental to all manufacturing processes, the total being a factory overhead charge Conservation and the economic use of materials are therefore of the utmost importance The danger of waste is specially great in small parts and tools and indirect materials of all kinds Apart from deliberate wastefulness, industrial wastes may arise in spoilage or shrinkage of materials during manufacture or storage, failure to dispose of the material removed during manufacture to the best advantage, not reclaiming by-products and not salvaging work rejected on inspection Some rejections are inevitable in every process, but incentives and training in waste reduction will keep the number down, and the salvage committee or department can frequently effect a considerable saving by finding the reason and providing against their recurrence The various methods of reclamation by welding, electroplating, and other forms of metal deposition, using waste for smaller components, etc , should be exhaustively studied to reduce the waste bill

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The Efficient Control of Production Fazakerley (Gee & Co)

Efficiency Methods McKillop (Routledge & Co)

Recent Progress in Engineering Production Lindley (Ernest Benn)

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CHAPTER VII

CONTROL OF PRODUCTION

HOWEVER vital it may be to ensure that the planning of production, as discussed in the preceding chapter, is carried out, it is of equal importance that steps be taken to establish control of production to ensure that the plans *are* carried out It is clearly impossible to visualize any control of production without a carefully laid plan and equally fatuous to attempt to plan production unless it is possible to exert the requisite degree of control For this reason it is sound policy to ensure that one person or department is held responsible for both the planning and the controlling of production

The degree of control to be established will vary with each concern The over-riding consideration is clearly the economic one of deciding if the procedural arrangements and administrative staff expense involved in the planning and controlling operations represent profitable expenditure

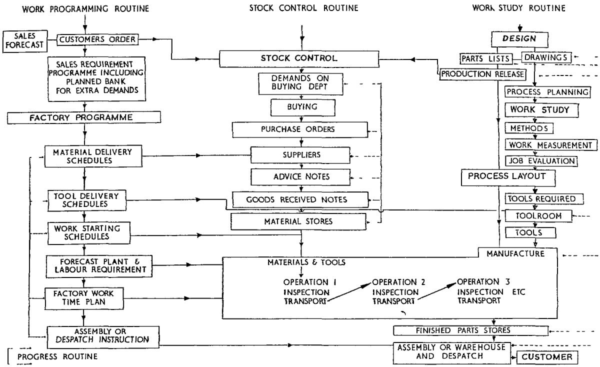
There will, in any case, however, be several departments of the control arrangements, the principal ones being—

Control of work methods
Control of material availability and use
Control of work sequence, or work programming
Control of output
Control of quality

We propose to discuss these aspects of control in this chapter In doing so, however, we cannot omit the importance of cost control as a continuous and overriding factor it is, indeed, of such importance that a separate section of this book must be devoted to the matter—see Chapter X The main channels of production control routine are illustrated in Fig 50

METHODS DEVELOPMENT AND WORK MEASUREMENT

The accurate measurement of output is of great importance in every factory, both as a measure of efficiency on



By courtesy of Industrial Administration Group

FIG 50 MAIN CHANNELS OF PRODUCTION CONTROL ROUTINES

account of its close relation to costs, and as a basis of piece or bonus systems of wage payment

A production order is divided according to the nature and sequence of the work This working plan is subdivided into processes, operations, and motions A motion has been defined as a complex group of actions by a worker in the course of production They are units of his labour which has to be paid for, and can only be paid for in proportion to its productivity Hence the importance of ensuring its highest efficiency

Motion study aims at eliminating wastefulness resulting from unnecessary, ill-directed and inefficient movements with a view to achieving maximum economy of effort Not only does it seek to eliminate superfluous movements, but to combine and co-ordinate successive motions into a natural rhythm which is the most efficient way of doing a job To achieve this the best possible working conditions must be provided, including suitable tools, height of work, position of workman, freedom from danger and mental strain, and so on Motion study is a great help in the training of workmen since any job can be learned more readily if reduced to its simplest elements The general principles of motion study include therefore finding the most efficient method of doing work and training individuals in its practice

This achievement of and instruction in the most efficient way of working eliminates the mental struggle of indecision, reduces the training period, and permits higher speeds of working without additional effort

Not only is the period of training diminished by motion study combined with psycho-technical principles, but higher levels of performance are attained by the trainees, in fact, the efficacy of training may be rated in the following order—

1 Based on motion and time study
2 Trained by foreman
3 Copying an older worker
4 Self-trained

The pioneer work of Taylor on motion study was considerably amplified by the Gilbreths, who put it on a scientific basis by the introduction of the process chart, micromotion and chronocyclegraphs The classical studies of shovellers and bricklayers were followed by investigation of many engineering operations and assembly work, resulting in a reduction in the number of movements and an increase of production without fatigue The introduction of a photographic technique permitted the study of permanent records at leisure and enabled the workman to be shown where he was losing in motion and time More recently the application of the cine-camera has enabled very fast movements to be recorded and analysed In this micro-motion study a chronometer is included in the picture and the operator may be photographed against a squared or sectioned background stereoscopically, or in two directions at right-angles so as to record movements in three dimensions

In engineering tasks motion study brought to light the importance of the work place or surrounding equipment, in which there were sometimes more variations than in the movements of various workmen The defects most frequently revealed included unsuitable tools, wrong fixtures or aids to production, wrong postures, wrong methods of handling parts or tools, wrong lighting of the work, wrong location of work or auxiliary equipment, wrong movements Motion study should be applied, therefore, not only to hand movements but to as wide a field as possible, including movements of materials and tools and to whole production schemes

Operation analysis may result in slight modification or the adoption of new methods, but, in any case, ends in the precise specification of working methods which may be issued in the form of instruction cards for operations or assembly Training should extend from manager to operative, until the whole of the personnel becomes motion-study conscious

Instruction in the best ways of working includes safe working and it is found that where methods are based on scientific analysis, they are methods which result in the minimum amount of fatigue Investigations have shown that accident rates are reduced where proper methods have been taught as compared with leaving operatives to pick up methods of working from experience

MEASUREMENT OF LABOUR

The use of time study is twofold a measuring stick for individual efficiency and a basis for wage payment To pay for work on the basis of results demands some means of fixing the compensation for each unit In the past, rate fixing has been mainly a matter of guesswork or intuitive judgment of what an efficient worker should perform The measurement of human effort is, however, an extremely difficult problem, unlikely to be solved in a fair and accurate manner without industrial experience combined with psychological knowledge and the use of scientific method The last factor involves experiment, measurement, and elimination of variables In seeking to determine the number of hours in which an average man can do a given piece of work, it is first necessary to standardize the method and conditions of work and to define what is an average worker Time must then be considered from the point of view of the workman, the equipment, and the work Production time is only one constituent of job time, there are also preparation time (e g consulting the foreman, getting tools, etc), setting-up time, adjustment time, idle time, and so on Idle time may not be the fault of the workman, but of the management—or shop conditions, transport, etc It is unscientific and wasteful to commence the time study of a job without having fixed the method and the conditions of the job Time study has two sides, mechanical and human, and they must be dealt with in this order

ANALYSIS BY TIME STUDY

The successive stages of time studies are—

(*a*) Analysis of work
(*b*) Standardization of methods
(*c*) Making the time study
(*d*) Analysis and criticism
(*e*) Utilization of results

(*a*) ANALYSIS OF WORK A job consists of a number of operations, an operation of a number of motions, and a motion of a number of actions The first step is to analyse the job, split it up into its constituent elements and examine each operation critically An overall perspective is essential, the degree of subdivision of analysis depending on whether we are concerned with jobbing, batch, or mass production Production consists in moving as well as making, and the time spent in production operations may involve the following preparation, making records, obtaining materials, setting up machines, loading and unloading, manipulating machines and tools, resharpening tools, gauging and delays, all in addition to the effective work In other words, we are concerned with floor-to-floor times, not merely the period of effective production In a work period the workman works longer than the machine, and the machine longer than the material is worked on, thus

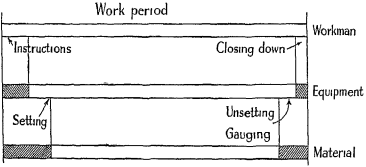


FIG 51 WORK PERIOD ANALYSIS

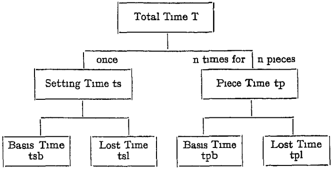
The diagram makes no allowance for lost productive time in interim work adjustment and gauging

The advantages of time study are to call attention to equipment and methods and also to all sources of lost time in addition to unsatisfactory speed of working The total manufacturing time is divided into two parts preparation, handling and adjustment, and effective work

Thus—

Lot Time for n Components	
Set-up, handling, and adjustment	Part sequence time multiplied by n

This may be set out in more detail as follows—



$$\begin{aligned} T &= ts + ntp \\ &= tsb + tsl + n(tpb + tpl) \end{aligned}$$

(*b*) STANDARDIZATION OF METHODS Any job consists of the following constituents materials, equipment, working conditions, methods, and performance Before studying performance it is necessary to see that materials, equipment and working conditions are standardized, that the quickest and best methods of performing each operation have been ascertained and unnecessary movements eliminated Inspection requirements must be settled and the stage cleared for attention to the final variable, the performance of labour

Personnel Time-study Men Too much importance cannot be attached to the personality of time- and motion-study men They must be chosen for their tact, calm, patience, analytical powers judgment and accuracy as well as their technical knowledge, training and experience Other character requirements are determination, conscientiousness, orderliness The intellectual qualities should include quickness of perception, short reaction time, a critical eye and power of convincing others They must possess the psychologically right attitude to their job, understand the operator's attitude to work and be capable of creating interest in the work and belief in their fairness and honesty of mind The time-study man should lend himself to no stunts He must take care to see that the men studied are acquainted with the machine, the tools, the methods and organization of the shop, are of average ability and are in the right temper The co-operation of the foremen and supervisors should always be sought, and also that of the trade unions

Operation	Time in Seconds				
Pick up part and place in jig					
Lower drill to part					
Drill ¼ in hole					
Remove piece from jig					
Blow out jig					
Overall time					

FIG 52 TIME-STUDY RECORD SHEET

The Worker Under Observation The workman timed must be an average worker, who has been employed for a sufficient time to become reasonably skilled in the job It is essential to overcome the scepticism, or even worse, on the part of the workers, and obtain their co-operation They must be thoroughly informed of what the firm proposes to do and what its aims are The nature of overheads must be explained to them so that the operatives will understand how these will be decreased as output is increased, whilst their own wages will go up with increased skill and proficiency The firm must give an undertaking not to cut rates once they have been scientifically established and agreed upon by both sides, that is, unless new machines or methods are introduced, when the job will be restudied Without confidence, a good deal of the value of time studies is vitiated Management should remember that the old bad methods of rate guessing and cutting have been a long time a'dying!

Before commencing a time study the observer will ascertain if motion studies have been carried out so that the planning of work, work places and appliances are satisfactory and the operations can be performed in the correct sequence without interruption, and whether the human effort involved is at a minimum and the worker's skill and diligence up to average

(*c*) MAKING TIME STUDIES—THE INSTRUMENTS USED The apparatus used in making time studies is generally the stop-watch with a decimal scale It may have one or two hands and a reversing mechanism, or two watches may be used Alternatively, and particularly for short intervals of time, recorders may be used

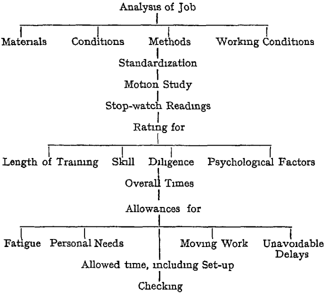
The stop-watch is usually attached to a time-study board carrying the time-study sheet The observer has to note the time of the operation under investigation or its constituents and make a record on the time sheet, an example of which is shown on page 216

In metal-cutting operations relevant data such as the revolutions per minute are obtained from an indicator, and the cutting speeds by the use of a speed slide rule

(*d*) ANALYSIS AND CRITICISM—ALLOWANCES When a series of observations has been recorded the standard or average time or performance has to be ascertained The simple arithmetic mean is usually adopted, though some prefer the minimum, others the modal or most frequent performance The coefficient of fluctuation of the observations is measured by dividing the average by the minimum The next step is levelling between the performances of different operators The time-study man must judge the work observed from the points of view of skill, effort or application, conditions and consistency and record the corrections to be made under these headings

From such work the standard operating time can be fixed and now the question arises of the time to be allowed or task time The experienced man will know what allowances are necessary, that they include factors for fatigue, personal needs, moving the work, unavoidable delays, etc in a general way about 25 per cent of the operating time is allowed for these factors

Summing up the stages of time-study work, we have—



Allowed Time = Most probable time × Rating × Allowance

The question of set-up time has also to be considered For long runs it might be included in the sequence piece rate, but if the set-up and preparation is lengthy or there are only a few off the operation, it obviously cannot be dealt with in this way, and a special first piece time may be allowed, or the man may have to be paid his standard time rate during this period

If the time-study man's allowed time is subsequently challenged he would, of course, carry out investigations such as the following, before repeating his own study

Is the machine working properly? 2 Are there faults in the material? 3 Are there faults in the tools? 4 Is the workman awkward in his methods and a demonstration necessary?

Formulae and Diagrams The application of time studies is not limited to the part or component on which they are performed Standard data having been established for fundamental or characteristic work, a chart or formula may be made out from which may be read off the allowed time for jobs on which no data have been taken The use of speed and feed charts has been known for a long time, and, if data are obtained on the maximum and minimum sizes of work done on a machine, interpolation may be made with a sense of reliability Extrapolation is not necessarily so satisfactory If, however, all work performed on a machine is classified and standard chucking methods, jigs, tools and other equipment used, a small number of studies will give a formula utilizable over a good range

The formulae can, of course, be checked as and when desirable The use of formulae and charts is not, of course, limited to machine work They are applied to assembly, moulding, welding, drop forging, and so on

When plotting a few actual time determinations with a view to establishing a formula, it may be found that they do not apparently lie on any simple curve In some instances, however, a correction for some simple relationship, such as the ratio of the length to the thickness, may reduce the observations to some obvious linear relationship between time and size of work (*e*) UTILIZATION OF RESULTS—DETERMINATION OF PIECE-WORK WAGES The efficiency of linking up wages with output is apparent to all—wherever the performance of labour can be measured, it should be placed on an incentive basis of payment Piece rates can be fixed by estimation, calculation, comparison, or time studies Estimation is the oldest method and is still used subconsciously by many managers who prefer their experienced guesses to more scientific determinations It has, however, led to many serious mistakes, rate cutting, and labour trouble Calculation of piece rates from knowledge of machine performance may also be unsatisfactory, as it does not take into account variations in shop conditions and materials, and omits any allowance for the human factor

Collection and arrangement of previous results with a view to establishing piece rates on a comparative basis has its uses, but, without a large degree of standardization, comparisons may be subject to serious errors

The only scientific method of fixing rates is by time and motion study, which should be the foundation of all incentive wage payments, guaranteed against change so long as conditions and methods remain the same Past rate troubles have been caused not only by lack of faith in the management's intentions, but also by inefficient production knowledge and inefficient production control Output is not and never can be a matter of workmen's energies alone, and it serves no purpose to offer employees incentives to work harder in works which are semi-paralysed by inefficiency of plant and shop conditions Time and motion study directs attention to the latter prior to measuring the workmen's contribution

OTHER RESULTS FROM TIME STUDY

There are many other benefits from time and motion study besides constituting the basis of rate fixing In the opinion of some managers the determination of equipment capacities is more important The fixing of shop capacities underlies the laying down of production schedules, and the accurate determination of delivery dates By studying production from the standpoints of the worker, the equipment and the work, the attention of the management is directed to causes of lost time in either men or machines Shop defects causing unnecessary work are detected and more punctual flow of material is promoted Obsolete plant and shop methods are swept away and the management is kept informed of the economies effected by improvements Not only is time and motion study the only rational way of determining how long jobs should take, but also the only scientific method of forecasting labour costs with precision Time and motion studies, properly based on the principles of the psychology of work, are of great help to foremen in the achievement of their supervisory tasks Time studies are not something to be grafted on to the works organization, they must be an integral part of it, in which case they become a vital instrument to assist management

Time studies properly applied are a means of production control and maintenance of delivery promises They ensure reliable standards of performance and full plant utilization with avoidance of bottle necks By assuring the optimum output they reduce capital cost charges to a minimum

Just as the engineer prepares a detailed machine set-up, the time-study or work measurement department prepares a detailed labour set-up Its task is twofold—

1 *Analysis*—what the operative does, the methods used, how long is taken, the effectiveness of the worker, his skill and application

2 *Synthesis*—fixes the approved or standard methods or conditions, fixes operation times having regard to the effectiveness factor, builds up the operation times into the job time with due allowance for the various relaxation factors, establishes a fair basic task

Modern time study may be conceived as directional organization of the workmen's efforts It indicates that the management does not wish to transfer to the workmen the responsibility for output, as it presupposes the establishment of the best working conditions and fixes a basic rate on what it has been shown the average worker can do. It also shows that the management takes the responsibility that the programmes and schedules can be achieved without any undue driving by financial and other incentives. Whilst in the past a great deal of scepticism and opposition has been offered by labour to time study, it should in the hands of a fair-minded management prove an instrument for creating confidence. It is well worth while to create and maintain a reputation for fairness, as time study provides management with a valuable means of production control and cost control.

STOCK CONTROL

Successful achievement of production programmes laid down ultimately depends upon the control which can be established over production material stocks and supplies to ensure that the right quantities are always available at the correct time. In practice this objective may seldom be achieved, and it is then of vital importance to ensure that breakdowns in supply which are inevitable are rapidly corrected and that all possible action is taken to prevent them from arising. The responsibility for this important aspect of production organization is frequently delegated to a Stock Controller—the modern term for a chief storekeeper which more truly describes the job that is involved.

The stock controller is responsible not only for requisitioning materials on the stores list which have fallen below the budgeted reserve, but for the proper care of all materials after receipt on the firm's premises. His functions include receiving and recording, placing into store after receipt of the examiner's certificate, storing systematically and preventing deterioration, issuing only on authentic requisitions, keeping proper records of the movement of stocks and co-operating with the salvage and scrap reclamation department

The purpose of storekeeping is threefold (1) to have on hand, when wanted, all material needed by the works (2) to keep the investment in materials as low as is consistent with deliveries desired, (3) to know the cost of materials on each manufacturing order

After occupying for some time the position of the Cinderella department, the stores is to-day recognized to be of great importance in production control and effective works management The stores must be developed to the same degree of efficiency as the manufacturing department —if necessary, revolutionized to fit in with modern organization The provision of materials as they are needed may depend on the efficiency of the stores Delay or lost time may have a serious effect on the firm's deliveries Efficiency does not, however, mean elaborate arrangements

Stores represent money's worth and materials have to be accounted for as carefully and scrupulously as cash, or large losses may result Stores and partly-finished stock represent a considerable fraction of the capitalized value of the firm, on which interest charges must be taken into account to check if the capital may be more profitably employed otherwise In addition, the cost of carrying stores safe from fire, deterioration and damage is frequently of a high order

THE STOCK CONTROLLER'S DUTIES

The head stock controller is an important link in the chain of organization, and a man must have applied himself diligently to learn his job before he is fitted to take over this position of responsibility The standing of the material controller has inevitably been raised by the development of cost accounting which throws a more searching light on the monetary significance of stores control By dint of systematic and accurate storekeeping, the material controller can save the firm large sums of money, organizing ability is an essential requirement otherwise he cannot control the multiplicity of detail work involved in the inspection and recording of receipts, the planning of the stores and the employment of the storage space to the maximum utility, the maintenance of correct maxima and minima of stock, the physical handling in and out, and the issue and record of goods as they are requisitioned

The stock controller cannot walk round and do everything himself He has to organize so that every situation requiring action is brought automatically before him, such as the falling of stocks to a point that will permit his obtaining new supplies before a dangerous shortage occurs, the hold-up in consumption of any particular stock which may threaten an accumulation of obsolete material, any threatened deterioration or depreciation of materials, any non-receipt of loanable stores or non-return of chargeable containers The system, often very comprehensive, has to be kept going with a continuity and ease of action that will promote economy in its working

The dependence of contracts on outside suppliers sometimes proves the weakest link in the chain of production and it requires the most careful vigilance on the part of the storekeeper to ensure that he does not get caught out with a shortage of some material which the purchaser cannot replenish in time

The stock controller must be vigilant by nature to prevent the numerous wastes and leakages which are liable to occur in a stores He carries the further responsibility of seeing that all materials are booked out to the proper jobs or works orders Reliability of the stores organization is all-important as affecting the materials element in costing The stock controller must also co-operate with the purchaser, as we have seen above, with the drawing office or planning department to simplify the carrying of stock, and with the shops which he is there to serve The stock controller has, in fact, been said to perform the non-technical work of the production manager He is on a par with the senior shop executive men

LOCATION OF STORES AND BUILDINGS

There is obviously an advantage in having the storeroom situated as near as possible to that part of the factory where the materials are to be used so as to reduce handling to a minimum The stores may be centralized or departmentalized according to the type of enterprise It depends on the nature of the industry and the situation, size and arrangement of the other departments In large works it is usual to find a main or central stores with sub-stores in the shops, an arrangement which is comprehensive without being cumbersome At the main stores there may be located the purchaser's offices as well as the inspection and test departments

Proper attention must be given to providing a suitable building, or excessive working expenses will be incurred Whilst lack of stores space hampers operations by congestion, too much space adds to the cost Adequate allowance for growth must, however, be made

The storerooms must be adequately protected from theft, fire and other damage, with special constructions for housing inflammable materials if these are necessary to production There are no objections to multi-storey buildings if efficient hoists or lifts are provided The use of galleries is generally recommendable Good lighting, both natural and artificial, and proper ventilation must be provided

The stores buildings must be light and dry, have a specially good roof, and be designed with reference to the class of materials housed

LAY-OUT

The lay-out of a stores requires careful planning with reference to the purpose for which it is to be used, so that no definite rules can be laid down as regards design The lay-out must be simple and effective and will be governed by the four stages of handling stores, viz receipt, inspection, storage, and issue Before allotting space, the question of bringing in, moving and taking out supplies, and the provision of aisles of the proper width for handling the materials must be considered The arrangements for the receipt of goods should provide for the promptest possible handling Unloading platforms should be at truck floor height with facilities for opening, examining, and checking, adequate space being provided to avoid congestion in case the inspector is not readily available

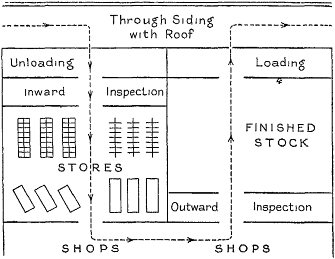


FIG 53 STORES LAY-OUT

Appropriate materials-handling equipment for internal transport must be provided, such as overhead cranes for heavy materials, conveyors for light materials, electric trucks, bogies, and so on If equipment is chosen to meet the needs of the materials, the risk of accidents is minimized Standing places for idle trucks must not be overlooked

The keynote of the lay-out should be direct accessibility, which is generally obtained by a series of aisles and sub-aisles in parallel rows Clear gangways also add to neatness The safety of floors, aisles, and fire passages should be ensured

Fig 53 shows a suggestion for a lay-out in which the stores is adjacent to the finished stock, and the incoming wagons, which have delivered materials, may be moved on and re-loaded with finished products

SECTIONALIZATION

Sectionalizing largely prevents overlapping and permits a more equitable division of duties and work Fig 54 shows how the stores of a large electrical engineering works was sectionalized

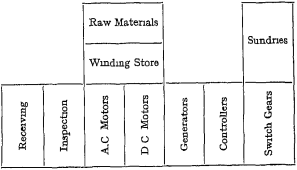


FIG 54 SECTIONALIZED STORES

In a smaller works the sections may simply be raw-material store, work-in-progress store, finished-parts store, and also tool store

The raw-material store is important and requires careful control as, owing to the miscellany of materials, there is a liability to leakage, especially of very small parts Valuable stores must be kept under lock and key In engineering stores it is usual to have a cutting-off division with saws and a guillotine, and care must be taken to prevent the formation of an excessive number of short lengths

The work-in-progress store is associated with, and may be under, the control of the progress department It is exceptional from the point of view that there is no permanent allotment of space Finished parts may be kept ready for assembly Where components are machined in quantities in advance of requirements they are usually put up in assembly batches

The finished-goods store is usually under the control of the sales department, which forwards appropriate shipping instructions It is usually run on a maximum and minimum basis The stock in hand always appears in the Ledger Account, which will be referred to later

The tool store issues small lots on loan Care must be taken that tools in store are in good condition and ready for use This store will be dealt with below in some detail

As has been indicated, the character of materials used by the firm affects the storage arrangements Some materials are not affected by the weather, and may be stored in open sheds, others need to be protected carefully from corrosion, such as machined castings and forgings, others again must be kept free from the access of moisture, and so on Petrol and other inflammable stores must be kept in a separate special place Of the various risks to which stores are exposed, i e fire, theft, deterioration from rusting, dirt, evaporation, the first two factors can be adequately insured against

STORING METHODS

The position of specific stores will depend on the difficulty and frequency of handling It should be arranged that those most frequently required are handiest Items should be counted or weighed before storing and arranged in issuable units Heavy stores may be placed in piles with a view to economy of space and should be cleared in rotation A uniform method of piling should be adopted so as to increase the accuracy and speed of inspection and count For the utmost utilization of available space a tiering truck is very convenient Lots should be separated from each other, and the old ones cleared up before new ones are started on Miscellaneous goods should not be stored in out-of-the-way bins or an obsolete collection may be formed, involving a waste of space and money It is good practice to keep the miscellaneous goods in the centre of the store

Light articles are stored in bins or racks according to the nature of the materials to be stored Lockers and bins designed to hold a given number of parts are often a convenience Wooden racks are cheap, quickly made, and do not mark or bruise delicate parts Metal racks are more durable, fire-resisting, free from splintering and breakage, and give more available space Standard steel shelving is now provided, and unit storage areas may be used as the basis of the lay-out

The essentials of good store practice are keeping every item in its assigned place and maintaining adequate but not elaborate records Sources of loss are to be found in the improper diversion of materials, waste of time in locating them, and, if overlooked for a period, the possibility that they may become obsolete and unusable

The rise and fall of stocks must be carefully noted When a balance is struck on the bin cards after each issue it must be compared with the stated minimum with a view to preventing shortage The fixing of maxima and minima will be dependent on business conditions, the estimated requirements, and the delivery time The advantages of fixing minimum and maximum stocks of materials are that the risk of running out is lessened, the replenishment of stores is easier, and the working capital involved in carrying stores is kept within desirable limits The minimum is the ordering point The maximum is usually two or three times the minimum, but the stock controller must use his discretion in the matter

CLASSIFICATION AND MARKING

The importance of classification lies in ease of identification and the minimizing of time and labour spent in locating stores It eliminates the confusion arising from different descriptions of the same materials and the use of different units of quantity Thus a carefully thought-out system helps to ensure accuracy in stores accounts and costs A standard description of each item must be agreed upon and a method of coding introduced It may be possible to adopt a code partially identifying the material designated The code may be numerical or symbolic, which allows for enormous expansion if required Related parts will have related numbers and be stored in close proximity, which will be an aid on issue for assembly If the system of "unit" stores is used, sets of units involved in particular assemblies or operations will be got ready in advance

The essentials of a good code system are that each symbol should be a unique and definite description of the product, and that the relation between the symbol and the product should be comprehensible to all employees Whilst brevity is desirable, it should not be at the sacrifice of informativeness

To assist the locating of stores, points of reference or "finger posts" indicating the lay-out of the stores may well be the first part of the code numbers, a further subdivision being shown by the cards at the top of a group of bins or racks The marking of the lay-out should be such that any intelligent person could take a copy of the code book or stores vocabulary and find his way to any item picked out at random, e g 1A22 might mean Aisle 1 Sub-aisle A, second rack down, second bin from the top

The above method of classification and marking is specially suitable for details, unfinished and finished parts, and finished units The scheme may be carried further, e g to link up with patterns and castings and even catalogue numbers, but bars, strips and sheets are usually stored separately To facilitate location of bars and sheets they may be painted at one end or corner, which also is a precaution against mixing

STOCK CONTROL RECORDS

The storekeeper's figures form an important part of the firm's commitments and the data the storekeeper must have readily available include not only the quantities on hand at any time or what supplies are available but also the total required for manufacturing orders, the amounts ordered to date, received, and not yet received, and the amount allotted to jobs

The forms used in a stores will naturally depend on the special circumstances of the organization as a whole, but the keynote should always be simplicity and convenience, and the forms should only have columns for absolutely essential information Full use should be made of the range of colours for the immediate identification of particular forms, such, for example, as the one used to indicate a shortage of delivery or wrong materials

It would serve no useful purpose here to go in detail into the wording of the various forms, as they must be drawn up to serve the special requirements of each firm The essential feature with regard to any form is that it shows the indispensable facts, and no others

The forms nearly always used, though there may be many others, include—

Stock Control Record

An example of a stock control record and its supporting documentation is shown in Fig 55

Purchase Requisition (Fig 56)

Goods Inward Sheet (Fig 57)

Summary of Goods Ordered, Received and Outstanding

Inspection Vouchers, including excess or shortage notes and rejected materials record

Bin Cards

Shop Orders on Stores (Issue Vouchers) (Fig 58), including foremen's vouchers

Return to Stores Credit Notes (Fig 59)

Completed Parts to Store Form

Temporary Loan Form
Stock Summaries, weekly or monthly
Movement of Stocks from Stores, weekly or monthly

The stores records constitute a running inventory and, if continually checked by sampling inspection, render a physical inventory involving temporary paralysis of the works unnecessary Not only is this old-fashioned nightmare eliminated, but the perpetual inventory has the advantage of permitting monthly profit and loss statements and balance sheets to be drawn up

Attention must be given to the amount of stores materials represented by work in progress For each department a standard is in some cases fixed, e g as a percentage of the cost value of the output Any deviations from this standard are noted and indicate whether more money than usual is being tied up in work in process A form covering the movement of semi-finished material from one department to another assists the cost office in valuing the material in process of production

BIN CARDS

Objections which used to be raised against the use of bin cards were that the extra labour and expense of keeping them up were not merited, that they were a duplication

REQUISITION FOR PURCHASE

Stores Order No
Date
Please supply for Job No for Stock

Description	Drawing or Specification	Quantity	Code No	Price

Required by *Signed*
Storekeeper

FIG 56

GOODS INWARD SHEET

Sheet No Date Received

Advice Note	How Delivered	Supplier	Order No	Packages	Condition	Particulars	Partial or Complete Delivery	Passed To

Signed Receiving Clerk

Fig 57

SHOP ORDER ON STORES (ISSUE VOUCHER)

Section requisitioning

Voucher No
Date

Reference	Description	Code No	Quantity		Posted	Price	Value
Job or Order No			Demanded	Supplied			

Signature

Fig 58

RETURN TO STORES CREDIT NOTE

Section returning

Receipt No
Date

Reference	Description	Code No	Why Returned	Quantity			Price	Value
Job or Order No				Serviceable	Repairable	Total		

Signature

Received Storekeeper Date posted

Fig 59

of other recording and that they became dirty and unreadable, were easily lost or could be torn up and fresh ones made out

Standard bin cards are, however, cheap and may be printed with headings such as the following Description, Code No , Location, Maximum and Minimum Stock with columns appropriately to record the movement of stock, viz the goods received, the amount taken out as per requisition, and the balance with dates, etc

Bin cards should be kept in the handiest position with the material, e g on the side of the bin, and kept if necessary in grease-proof envelopes, so that the stores and the card can be inspected at the same time by the checker, for example, during the continuous audit constituting the perpetual inventory The advantage of visibility of position of the bin cards is that danger signals affixed when stock has fallen to a minimum cannot be overlooked

A series of well-kept cards gives confidence The very fact that the storeman has to record all movements on a bin card impresses on him the importance of stocks and that the management regards them as a form of money

The daily check of random bins diminishes the degree of error, and reliable bin cards facilitate stock-taking Bin cards are the practical link between the physical stock and the stores accounts The bin cards and the storekeeper's records constitute a mutual check, and if the latter were accidentally destroyed, e g by fire, the stock position could still be ascertained

VISIBLE INDEXES

Documents referring to store movements are usually made out on the slip system to reduce writing and transcribing, and stores books kept on the loose-leaf or card system, which ensures their being current, obsolete matter being easily removed and filed Modern methods of recording stores attach importance to the principle of visibility in minimizing clerical work and facilitating control

The basic features of all stock records are—

1 Quantity ordered and balance on order
2 Quantity received, issued, and balance on hand
3 Re-order level
4 Average cost price of each item
5 Monthly recapitulation of issues for current and previous year The last point shows the trend up or down and permits orders to be placed with greater accuracy

A number of systems of visible card indexes are available on the tray and cabinet principle, either upright or horizontal, which are simple, durable and compact They may be posted if desired without the cards being removed Attention may be called to important items or features by the use of various signals

The great advantage is that the whole position may be seen from glancing through the system, and better control is maintained as regards both under-stocking or shortage and over-stocking of slow-moving items

Another visual system of stock control is the Kardex, in which cards relating to the various items are kept in overlapping pockets and are provided with a set of signals The cards are entered up to indicate the amount of stock on hand in weeks' supply, when the stock is at ordering point, when it is at a minimum and the position serious, which are the slow and which the fast moving lines, when the last order was placed, and so on

STORES CONTROL

It should not need emphasis that there is no special virtue in merely keeping records, the primary object is to exercise stock control In addition to a fair charge for interest on the money value, there are handling charges, rental values, insurances, stock-taking and auditing, charges for depreciation, price reductions and obsolescence These charges are estimated to total from 12 to 20 per cent The optimum value of stocks is therefore a financial question of the highest importance

The stores control system extends from the ordering of materials, through their actual storing and safeguarding, to their supply to the shops and assembly lines The requisites are a clear-cut procedure and the centralization of responsibility

A good stores procedure is a safeguard against waste of material, theft, and other losses It involves the use of permanent records of receipt, issue, progress and final disposal so that the goods may be traced wherever they may be and in order to indicate who is responsible for their safe custody at every stage

In every organization carelessness and misapprehension may arise, bona fide mistakes or slips occur when transferring figures from one document to another, e g from a requisition form to a stores record Apart, therefore, from following the golden rule that no supplies enter or leave without documentary evidence, the storekeeper must study the possibility of the occurrence of errors and make his own arrangements for their detection by suitable checking procedure, not only of figures but of actual quantities or weights With regard to issues, for example, he must obtain the signature of the man accepting delivery, this signifying that he has actually received the items set out on the requisition

The stores procedure for replenishing stock takes the form of a requisition to the purchasing department Of course, if the storekeeper requires components which the works makes, he advises the production department

With outside purchases the vendors may send an advice note or dispatch the materials with the invoice

When the goods arrive in the stores they should, in the first place, be signed for as received subject to count, weight, and inspection It should be remembered that everything that comes within the company's gates must be accurately recorded in the Goods Received Book There must be no exceptions The materials will be entered by the storekeeper and checked against the invoice The details generally entered are the date, order number, quantity, the name of the vendors, how delivered, condition on receipt, and inspection date Goods Received Notes are made out and sent to the purchasing department and the inspection department After acceptance of the goods, the storekeeper enters them up on his cards If goods are rejected they are retained in the receiving stores pending instructions from the purchaser, and a special list of all rejected material should be kept

Turning now to the consumption of material, issue commences with the receipt of the specification from the drawing office or planning department, either direct or through the progress department One copy goes to the store clerk and the other to the man in charge of the actual issuing of goods, who can begin work at once The clerk posts the details to the stores record cards, bringing down the number or quantity still available The storeman enters the materials out on the bin cards in the same way that the store clerk posts his records With the use of a specification list a foreman's requisition is not required, but there are some cases in which a foreman's demand note will be necessary In the issue of incidental stores some latitude must be allowed, but the manufacturing department concerned must be debited with them The store clerk's copies of the specification or stores requisition is sent to the costing department and analysed for the costing books

Materials issued in excess of the requirements of a particular job must be controlled by a Materials Returned to Stores Note, and no exchange is permitted unless accompanied by an inspector's report

Transfer of materials from one job to another must be discouraged and all materials passed through the stores and duly credited and again debited

The following description of a stores control system relates to a fairly large concern On the receipt of an advice note by the purchasing department, a copy of the requisition is sent to the receiving department On the goods being received at the central store they are checked before being signed for

A Goods Inward Note or Goods Received Note is made out in triplicate The first copy is sent to the purchasing department and the corresponding goods-on-order entry is cancelled The second copy is sent to the inspection department, and the third is retained

The inspection department makes out a form in triplicate, a copy being sent to the purchasing department and the receiving department, whilst the third copy is retained

If the goods are accepted, the purchasing department passes the invoice and the receipts department passes the goods on to the central or shop stores requiring them, or, if they are rejected, retains them until instructions as to their disposal are received from the purchasing department

The stores are laid out in conformity with an agreed classification, so that the incoming goods can at once be placed in the correct bin, rack or stack, even by an intelligent stranger once he is in possession of the code or vocabulary as it is sometimes called In addition to the consignment being entered on the bin card, the keeping of a stores record by the storeman gives an independent check

No issue from the stores is made without a proper authorization The requisition is made out in triplicate, a copy being sent to the stores, which retains it for recording purposes, a second to the foreman with the goods, and the third copy being retained by the department issuing the requisition The first and second copies finally come together in the costing department

For consumable stores or small items the foreman makes out a voucher in duplicate, one copy going to the stores and the other copy being retained, but ultimately the two copies come together again in the costing department

For any surplus material returned to the stores a credit slip printed in red is made out permitting the accurate booking of such transactions in a similar manner to that of material requisitions

The system outlined permits a triple check on stores, viz the comparison of bin cards, the storeman's record and the Stores Ledger The stores organization is duplex, the clerical and the actual handling sides being distinct but correlated

If a firm makes its own raw material, for example, in a separate works, store control involves the ordering of material in anticipation of demand, consideration being given to the period of manufacture of the raw material as well as its further fabrication and elaboration before delivery to customers A factory programme being established, the material must be ordered regularly and requisitions modified by the storeman to meet the developing market demand He has, therefore, to give his attention to the rate at which material is being taken out of his stock and adjust his orders to maintain his minima It will be seen that, if the raw material is prepared in a variety of forms and sizes, a difficult problem of stores control is presented

To keep accurate records of large quantities of materials and merchandise requires great care, and as the complexity of the work increases, orthodox methods of stock recording become slow and cumbersome To obtain a quick bird's-eye view of the stock position in large concerns punched-card systems are meeting with increasing use All parts are first codified, and a card punched for each part number showing the quantity and value in stock Receipts and issue cards are punched from requisitions and goods received notes or requisitions It is an easy matter at given intervals to sort and tabulate these cards under classification numbers and determine the balance in stock Weekly tabulations may be sent to the central stores department for them to issue, if necessary, a further supply contract or a manufacturing order, as the case may be

THE STORES LEDGER

The Stores Ledger is intended to catch up the total expenditure on stores over a trading period and indicate the value of stores on hand at the conclusion

On the debit side are posted incoming stores either as received or as shop returns to store, and on the credit are stores rejected and stores issued on requisitions Each side of the ledger may be ruled as follows—

Date Reference Quantity Price Value

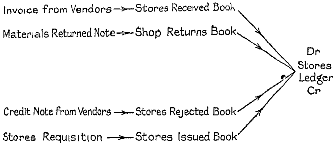

Invoice from Vendors → Stores Received Book
Materials Returned Note → Shop Returns Book
Dr
Stores
Ledger
Cr
Credit Note from Vendors → Stores Rejected Book
Stores Requisition → Stores Issued Book

FIG 60 STORES LEDGER ENTRIES

The relation between various forms and books used in connection with the compilation of the Stores Ledger is shown diagrammatically in Fig 60

The ledger is a kind of stores balance sheet, and the use it makes of stores values will be easily distinguished from that made by the job costing department It will be obvious that a store requisition may refer to a number of materials, so that for the present purpose it may be helpful to make out allocation sheets to which the various kinds of materials are posted from the requisitions, and similarly with any surplus materials returned to the stores

The effectiveness of the stores accounts will depend on the number of separate accounts in the Stores Ledger

The balance of the Stores Ledger gives a perpetual inventory value independent of stock-taking The figures must reconcile with the financial accounts, and, if finished goods are kept in the store, the stock on hand at the closing periods must agree with the Finished Stock Account in the General Ledger The Stores Ledger must not be kept by the storekeeper but in the cost office or accounts department as it furnishes a check on his records, in fact, the storekeeper may not know the value figures at all Some firms object to the storekeeper having knowledge of prices as, if information on cost leaks out, the effectiveness of control may be weakened Others consider that the storekeeper appreciates his responsibilities better when he has some knowledge of the money values under his control

VALUATION OF STORES

The valuation of stores in relation to cost and market values raises some interesting points, and is a subject on which there is some difference of opinion If materials are charged at the cost price of the quantities in stock the figures show the actual cost of manufacture and do not interfere with balancing the Stores Account in money value On the other hand, when it is necessary to charge a job with materials it may be that prices have fallen and the manufacturer will stand a good chance of losing a contract in competition with others who have access to the market The remedy is obviously not to allow stocks to accumulate in a period of falling prices

On the whole, it seems more practical to make use of the market price of stores, the prices of materials being revised accordingly Discrepancies occur, however, in the Stores Account as a whole, which represent a profit or a loss due to fluctuation, but this method affords a sounder basis for estimating for competitive purposes, as it deals with actual values rather than former values A distinction is drawn between profit or loss due to price changes or speculation and that due to manufacturing This method of charging stores is equivalent to treating the stores as a separate operating department

The prices used for stock-taking purposes should be the average of those of the remaining stock or the market price, whichever is lower In a falling market some provision may prudently be made for depreciation, but in a rising market the value of stores should not be written up

TOOL-ROOM STORES

The tool shop and stores should be planned according to the size and work of the factory It is a subject which has received a large amount of thought and consideration, and in the case of a plant being newly laid down, there will be no difficulty in selecting an approved plan as a basis for the lay-out In a large works there may be a main tool store with sub-stores in each department Sometimes tool storekeeping is part of the production engineering department as in Fig 12

Before considering arrangements for storage, careful consideration must be given to classification of tools, jigs, and fixtures, which in machine shops is highly developed Classification greatly facilitates identification of tools, simplifies the work of storage, and conduces to brevity of records, in this way effecting considerable economy of time and trouble

The arrangements for tool storage, whether in bins, racks, cabinets, or boxes, must occupy a minimum space and yet be adaptable and flexible so as to permit of expansion Metal racks have advantages in this direction Uniformity is desirable up to a point Accessibility and ease of removal are essential From this point of view steel equipment may save time Small consumable tools, such as files and grinding wheels, may be stored in trays Handy bins are designed to hold, for example, drills and reamers of all sizes In some works tools for each class of machine are stored in separate compartments

All tools, jigs, and fixtures, when not in use, must be kept in their allotted place and the system of recording receipt and issue should be such as to constitute a perpetual inventory

The tools may be recorded on stock cards kept on a maximum and minimum basis The chief storekeeper must exercise discretion in ordering tools according to the demand and the showing of his records, and keep the stock within reasonable limits, but no tool will be passed into store without inspection

The tool store is a lending department, the tools may be recalled at any time should circumstances demand it

The storeman has to know not only how many are in store, but also how many are in the shops and where

The method of issuing tools is of importance in preventing loss and saving inventory time Tools may only be issued against a requisition form signed by a duly authorized official, or against a tool list sent to the tool room by the planning department, but in any case the responsibility for return must be indubitably fixed It is generally placed on the operator to whom the tools are issued, who acknowledges receipt either by signature or the use of a token An old tool can only be replaced when it is returned to the store Sometimes a double-check system is employed, the issue of the tool being indicated under the tool number and under the number of the workman who is using it

Under the single-check system each workman is handed a number of metal tags bearing his number and he gives up one for each tool issued The storeman places it in the tool compartment to indicate the location of the tool in the shop, but there is no information available as to the tools that are in the workman's possession

The double-check system was devised to indicate what tools had been issued to each workman He gives up two tags for each tool, one being placed in the tool rack and the other on a hook bearing the workman's number To obviate the use of large numbers of tags, figures on the back indicate the number of tools which each tag covers

Tags are rather cumbrous and cardboard checks may be used in two parts, both halves being destroyed when the workman returns the tool Slips of paper are perhaps preferable to both tags and cardboard, as they can be slipped into card files Another advantage is that a number of copies can be made at a single writing, three copies being ample The first is filed under the workman's number, the second under the tool symbol, and the third handed to the workman, when this third copy is returned, number one would be destroyed at once and number two at leisure

Drills, taps and other small tools may be requisitioned in numbers by a foreman, who holds a small stock in his desk and can keep an eye on their consumption to prevent carelessness or extravagance and to ensure their economical distribution On return to the store after use, tools must be inspected so that defective ones may be repaired or reconditioned before they are put back in store and become available for immediate reissue This inspection on return results in economy in use For minor repairs a tool maker may be located in the stores and equipped with a drill grinder and a cutter grinder among other tools

FOUNDRY STORES

A pattern stores presents some interesting problems, including that of whether to store according to size or in batches for which the patterns are required The former method saves space and the locating of specific numbers is easier It requires closer attention, however, when a change in design occurs to see that each relevant pattern is altered The latter method simplifies sorting out, as it is simple to withdraw a complete set The clearance of obsolete patterns is facilitated, and it is easier to see if a set is in good condition

In any case, a card index should be kept with a recording system which is independent of the man who keeps the index

PROGRESS WORK

Progress is one of the main functions of factory administration and makes the department one of the most important units in the works organization Production cannot proceed as a haphazard adventure without co-ordination The time factor in production is increasingly of vital importance, and progress control has little or no foundation in the absence of prior knowledge of the time every operation takes in the plant available

The object of the progress department is to see that production is on time It exists to ensure that all productive activities are arranged and co-ordinated so that customers receive their goods at the specified dates It keeps track of all work as it goes through the factory with a view to obviating any delay and ensuring that the planned instructions and schedule are adhered to, every operation, machine section and department is kept under supervision to prevent congestion or gaps and to ensure an even flow of work, with which, of course, production is most economical Supplies are obtained on time and work is synchronized so that hold-ups are prevented in production and assembly and the plant is maintained at capacity production

Time, quantity, balance and co-ordination are the four prime factors of progress work Its commercial advantages in enabling the firm to keep its commitments are obvious The question of delivery is treated on a scientific basis and goodwill fostered among customers In addition, orders may frequently be obtained by a firm with a reputation for keeping its word over the heads of firms quoting lower prices, but with no assurance that promised deliveries will be maintained

THE PROGRESS MANAGER

Progress work must be done whether it is organized or not, but it is unnecessary to emphasize at this stage the efficiency of specialization In spite of the importance of the progress department, it must not, however, be unwieldy or over-staffed, the criterion of profitability must, as always, be applied The essential feature is that the department must be capable of doing what it sets out to do The progress manager has to see the programme through and get the best out of what is available Obviously, he must be strong enough to enforce his instructions It was for this reason that he was constituted a senior or major executive in the illustration of the line and staff type of organization shown on page 38 To limit the function of the progress manager to mere chasing and allow the production men to say when a piece of work will be done is a parody of management and the firm should delete the name of the department from the office door in such circumstances It is true, of course, that co-operation is as essential a quality in a progress manager as in any other works official, but, if his authority is stultified, the work of the planning department also is rendered ineffective and wasted

The progress manager, therefore, must not only have a strong personality, energy and push, but also a great deal of tact, for, as everyone with works experience knows, the work of co-ordinating the various and often contending factors in the organization is all too frequently very exacting Progress control is only achieved by the co-operation of all concerned The manager must have a good knowledge of shop conditions and procedure or he will not be capable of bringing the "correct" pressure to bear on such diverse departments as the pattern shop, foundry, machine, fitting and assembly shops, or testing and dispatch departments, as the circumstances may demand

As the progress manager carries the responsibility of achieving delivery by the promised date, his attention is naturally concentrated on matters which hold the possibility of delaying or limiting production, whether it be a question of supplies, production or movement of components, or lack of balance and synchronization He must be capable of discerning potential as well as actual weak points in the production programme and obviate delays by anticipating their likelihood to occur He must put each job on the production line at its proper time and ensure the correct sequence Rush orders, even in well-organized works, are difficult to put through, and the progress manager must devise a suitable procedure to deal with specially urgent jobs As a general rule, however, the issue of priority forms should be restricted and used only as a last resort To carry out his difficult job the progress manager requires a systematic mechanism of records, including tickets, notes, summary sheets and control charts, but there is no infallible system, intelligence applied to the particular firm's conditions is more important

PROGRESS OFFICE WORK

The progress department ensures that supplies and tools are available and then issues orders for each operation in proper datal sequence Promptness of issue is essential, any waiting time is, of course, a direct charge against the progress manager

The progress office is the centre of a continuous flow of documents bearing on the production position Job lay-outs are received from the planning department, delivery and shortage notes from the stores and advices that materials are ready for issue, tool completion notes from the jig and tool department, rate lists from the rate fixers, inspection notes from the inspection department, details of movement of parts from the shops, and so on

It will be seen that progressing is far removed from haphazard chasing, though chasing is an important part of the work, in fact, it is essential if advice notes are not received at the time they are expected As far as possible, however, the system should arrange for information to pour into the department automatically There is only a need to chase round when production is out of step with the schedule Progress control is impossible without an efficient organization

Daily or more frequent reports from the various departments permit the progress manager to check off that work is proceeding as scheduled Delay reports enable the management to fix the responsibility for broken promises as well as to decide on the action required to correct the situation

Progress recording should synchronize with the development of production facts, constituting a kind of cinematograph film of the situation which unrolls before the eyes of the management In fact, progress control has been described as dynamic graphics In industries where production factors vary rapidly, recording must be expeditious and, when possible, records may with advantage be made by the use of documents that are already necessary for manufacturing purposes

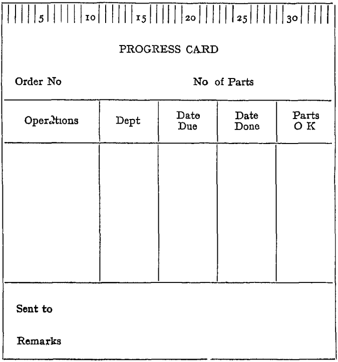
RECORDS

The records of the progress department will vary with the type of production

The progress sheets will show details of every lot in production, the whereabouts of each job, what has been done and what remains to be done, whether the jobs are on time or behind and, in the latter case, the causes of the loss of time, and the due dates Orders in arrears will be thrown up in relief In other words, the progress sheet will record every incident in the carrying out of an order from the date it was received and the works instructions issued to the dispatch date

A simple form of progress card is shown in Fig 61 To the time scale in days along the top the progress clerk may attach tickler tabs to remind him of the date the particular operation in hand should be completed and the work passed on to the next department

Another form of progress card has the top horizontal scale ruled off in man-hours, the operations 1, 2, 3, etc , being inserted at the time they are rated to commence The operations are then struck through as they are completed and, if there is divergence from schedule, a note is made of the reason Tabs may be clipped on to the card



5 10 15 20 25 30

PROGRESS CARD

Order No

No of Parts

Operations	Dept	Date Due	Date Done	Parts O K

Sent to

Remarks

FIG 61 PROGRESS CARD

to show when a job is held up, the colour of the tab indicating the cause

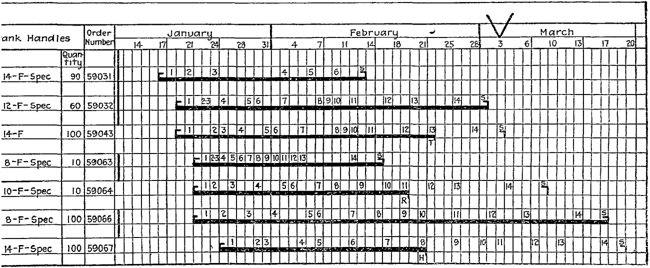
Production data in large concerns are complex, and managers cannot keep the details in mind To maintain control, it is necessary to have a visible system of records whereby the production information is centralized and the manager can see at a glance the stage attained by each order Fortunately, progress records are flexible, and it is not usually difficult to adapt a system to meet the conditions of a given works The records can be made to move at the same pace as actual production, and each order or component can be located at a glance, not only as regards its stage of progress but also its position in the factory Attention is drawn immediately to standing or waiting orders, and priority can be given to meet the exigencies of the manufacturing position

The proper starting-point of a production schedule is the delivery date owing to the undesirability of locking up money in materials and work in progress longer than necessary Working backwards with a knowledge of machine capacities and the time for the receipt of raw materials, the progress department is able to determine the date on which to initiate the order

FORMS OF PROGRESS RECORDS—GANTT CHARTS

The Gantt chart was referred to in Book I (Chapter VII) as a mechanism for recording many management control figures, whether in connection with planning, production control, stores-keeping, cost-keeping, or wage payments Its value was indicated as a method of presenting the facts of any situation in relation to time, the charts being easy to compile and easy to understand They are simple and compact and can be applied in any business irrespective of trade In the present chapter we are concerned with the use of this form of graphic representation for the comparison of production progress with the work planned The charts show the progressive increase in quantities in relation to a proposed schedule, and, if the anticipated progress is not being achieved, they show the reason why Such a record of facts in relation to time indicates if the plan has fallen short, e g whether delivery can be made on time, fixes responsibility and compels action in regard to the situation revealed

Gantt charts are drawn on printed or machine-ruled paper, and the record becomes merely a clerical task and



Reproduced from "The Gantt Chart

FIG 62 A GANTT PROGRESS CHART USED IN A PLANT WHICH MANUFACTURES TO ORDER

the executive is able to concentrate on inquiry and action, rendering help where necessary The manager does not need to follow the detailed progress charts, but charts of key operations or summaries The charts emphasize that time is the most important element in production, and by keeping all the promises and plans before him the manager is able to concentrate on the most urgent points

Dept										
Machine	No 1	Jan 12 Monday				Jan 13 Tuesday				
Press		—	—	—	M	—	R	—	—	Legend— M Lack of materials R Repairs T Lack of tools S Waiting for set up P Lack of power O No operator
Drilling		O	—	—	—	—	T	—	—	
Broaching		S	—	—	—	—	—	P	—	
Total		—	—	—		—	—	—		

FIG 63 GANTT MACHINE RECORD CARD

threatening delay, and if necessary give advance notice of postponed delivery Fig 62 shows a progress chart for work made to order

The student will have no difficulty in seeing how such a chart could be drawn up to represent work where manufacture is continuous The amount of work scheduled for any period may be indicated by a figure at the left of the space, thus $|^{20}\ |^{20}$, and the amount of work at the end of the period or up to any specified time may be shown by a figure at the right of the space

A progress chart shows what is to be done, what is done, and what remains to be done Gantt charts may, however, be used for many other purposes in production control Machine records and man records indicate if time is being spent to the best advantage and, if not, why A machine record card is illustrated in Book I, but a simple form may now be of interest (see Fig 63)

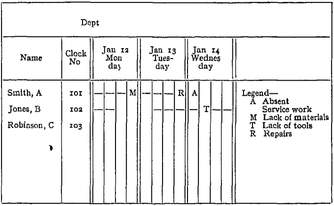


FIG 64 GANTT MAN RECORD CHART

Similarly, a record of each operator's time may be kept A summary analysis of time is of value in determining the time loading of the plant, and to give a bird's-eye

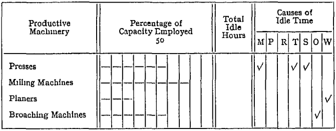


FIG 65 GANTT SUMMARY OF IDLENESS CHART

view of how fully the various sections are employed Idleness of plant loads the overheads and must be kept down to a minimum Fig 65 shows a suggestion for a Summary of Idleness Chart

Alternatively, a card may be made out for each type of machinery and the first column vertically might refer to consecutive weeks Of course, where ticks are given in the diagram actual hours would be inserted in practice

LOAD CHARTS

A load chart shows the work to be done on uncompleted orders or work ahead not commenced yet It is usually subdivided to refer to each class of productive machinery, the time scale being divided into working hours per week or per month The chart gives an analysis of the situation with regard to the total hours of work ahead

One may see at a glance whether some machines are over-loaded and it will be necessary to buy new ones, or whether congestion may be obviated by other means, e g working overtime or putting on a second shift On the other hand, it may be apparent that there is not enough work for some machines The load chart is also of service in quoting deliveries for future orders, what orders are needed and what kind must be refused The chart will indicate how many men will be wanted and whether it will be necessary to work overtime or part time In other words, the equipment, the hours of work and the operators are adjusted to the work ahead

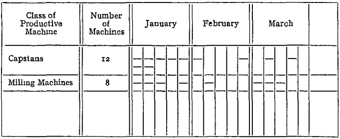


FIG 66 GANTT MACHINE LOAD CHART

It is difficult to see how progress can be carried out at all without load charts, which serve to indicate not only what delivery dates are practicable but also whether the maximum production capacity of the works is being used

They assist in setting pace to the works and permit no laggard sections Without them overloading may not be suspected until failure of delivery dates results in ill-will and even claims under penalty clauses

We have referred above to work planning and, if the orders are planned on lay-out charts, it reserves machine- and labour-time in advance for every operation through

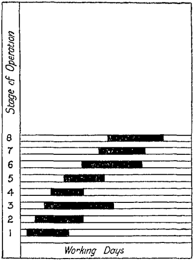


FIG 67 BAR PROGRESS CHART

which the products have to pass This indicates to the progress department the times to release work and to arrange for dispatching the completed products

All unfinished orders are shown as a load ahead in days or weeks for all groups of machines or key operations

BAR CHARTS IN PROGRESS WORK

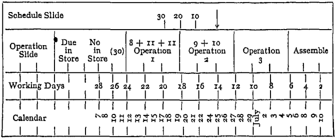
The uses of bar charts have been described in Book I, Chapter VII, but they cannot be applied in so versatile a manner as Gantt charts to production control They may be useful on occasion to record the planned time and the progress of work on a job or contract In constructional work, for example, it may or may not be necessary to await the completion of the first stage before setting to work another group of craftsmen, and the practical requirements of the job can be set down as a series of stepped rectangles, which not only ensures that each operation shall be commenced at the correct time, but each rectangle may be filled in to indicate how far the work has proceeded at any particular date When a firm has a number of contracts in hand, the charts indicate at a glance when each type of craftsmen will be available for commencing on the next job, by which time, of course, materials and plant will have to be got on the site

One method of control adopted in a large automobile manufacturing concern is to prepare a summary of production details in a loose-leaf book, one page for every day of the year, indicating budgeted output, actual figures, reasons for differences and comparison of any day with the same day in the previous year This enables the higher control to be fully conversant every morning with the previous twenty-four hours' achievement

CONTROL BOARDS

Control boards vary according as they are employed in mass production, e g in textile industries and some motor-car firms, or batch production In the former type of manufacture, the general characteristics of production are dealt with over a long period and the exception principle of control may be applied, whilst in the latter type detailed records are given over shorter periods

A control board is a device for automatically indicating the progress of the work It ensures that the production facilities are put into operation progressively at the rate provided by the schedule Control boards are mainly used for repetitive production but may, of course, be applied to batch or lot production For a complete product a control board is rather a complex mechanism, but the principle can be illustrated by confining attention to a single unit The device consists of movable horizontal tapes or slides as in a slide rule (see Fig 68) Time is, of course, the horizontal reference, and the bottom slide is marked off in days of the calendar The slide immediately above is marked off on the same scale, but in the reverse direction with working days, i e with its zero set at the delivery date The third slide is marked off with the number of days required for each operation, including time needed



Operation No 2 is one part behind schedule

FIG 68 CONTROL BOARD UNIT

for getting the raw material into store The fourth or top slide governs all the acts for which the board serves as a guide The movement of this slide, which is moved forward each day, initiates each event at the time it is scheduled to take place On the operation strip, the number of parts completed each day is recorded For any given operation the schedule slide is calibrated as follows a length equal to the number of days attributed to the operation represents the number of components to be made If work is progressing according to schedule, the total figure posted on the operation slide will correspond with the figure immediately above on the schedule slide

The principle outlined may be extended to apply to every component of the final product by means of the complete control board, an operation slide being allotted to each component A movable plumb-line enables the figures referring to any operation to date to be compared with the scheduled output If desired, the board may be photographed (say) once a week, so making a permanent record

THE CENTRALOGRAPH

An interesting example of production control applied in mass production works where expensive machine tools are

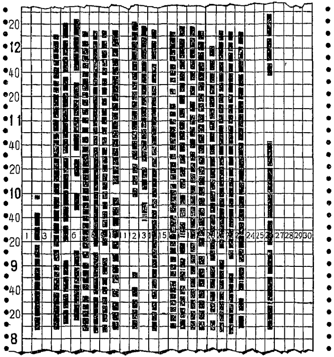


FIG 69 SPECIMEN CENTRALOGRAPH RECORD

employed is the Centralograph This machine is a recorder installed in the manager's office and indicates whether each machine is working or standing

The record (Fig 69) is a band of paper with the time element indicated down the sides in hours and minutes of the 24-hour day The paper band is unrolled by a clockwork mechanism engaging perforations in its edges Across the width of the band divisions represent the separate machine tools or capital plant When a machine is working it makes a line in the appropriate division, so that if work is proceeding according to plan the record consists of a number of black lines When a machine is standing no mark is made on the paper A short blank may, for example, indicate that the machine is being loaded, a long blank that tools are being attended to or some hold-up has occurred

The manager has continually under observation these blanks on the records, indicating that idle machine-hour oncosts are mounting up The write-up occurs absolutely in parallel with the job itself and thus enables him to observe whether the production plan is being adhered to, not some time after when nothing can be done about it, but whilst the job is actually being carried out

KARDEX WORK PLANNING BOARDS

Work planning boards for allocating plant capacity and controlling machine loads may be built up from a series of horizontal channels containing strips of card cut to a length equal to the estimated time for the job The strips butted end to end in the channels show the individual jobs and the total allocation of work for each machine At the top of the board is the time scale graduated in hours or weeks and capable of adjustment to allow for overtime Re-allocation of work is made by simply removing the strip representing the work from one position to another or from one channel to another Time lost or gained against the planned time is registered by moving the channel itself to the right or left, and a colour scheme may be arranged to show at a glance the amount of time lost or ahead of schedule The effect of departure from plan on other jobs is also indicated and the consequent adjustments required are clearly brought out It is obvious that by multiplying the channels the load on any number of machines may be visualized or the position of any number of processes indicated A cursor permits the jobs to be read off against the master time-scale The planning board may be photostated if it is desired to record the position of all jobs at any given time If desired such a board can obviously be arranged vertically with a horizontal cursor for time-scale reference

JOBBING SHOP BOARDS

The difficulty of progress control in a jobbing shop has always been acknowledged, yet it is practicable at little cost The following scheme was applied in a works of about 30 employees

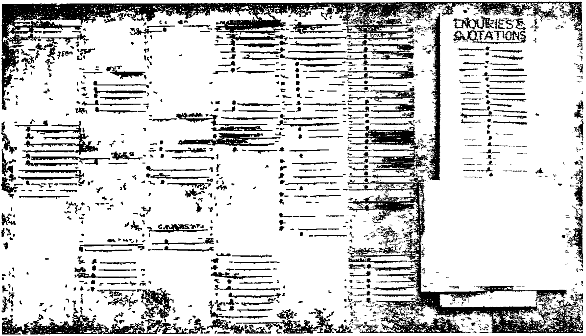
Progress control is carried out by means of the board shown opposite This was designed to cater for 300 jobs, the firm having over 200 jobs on its books at one time ranging from one off to several thousands off

The progress board is 7 ft by 4 ft and has on it several rows of pins between which slips of stiff paper 8 in by ¾ in in size are inserted Each slip of paper represents a job, and has upon it the following information—

(1) Job No (2) Description (3) Number off (4) Date received (5) Delivery Date (6) Drawing No (7) Customer's initials (8) Material column (9) Columns for the operations (10) Number delivered (11) Remarks

This progress slip is typed out by the clerk at the time of making out the job sheet and is fitted into position on the board in order of job number and under the appropriate heading The headings are arranged from the description of the article

When an operation has been started a mark (/) is made across the appropriate column and crossed thus (X) when the operation is completed If it is only part completed, then the number of parts is inserted beside the single stroke thus (/4) and the cross stroke is not added until the full quota of these operations has been completed, and so on up to the delivery stage



WORK PLANNING BOARD

Large-headed green, yellow or red pins in front of the strip denote whether the material is in the stores, ought to be chased, or is definitely late When the material comes in these pins are moved on to the slips in the customer's initial column and indicate whether the job is proceeding according to plan, needs pushing, or is behind promise

The progress slips are entered up daily by the clerk from the time sheets, as the workman filled in on his time sheet the operation and number worked upon and thus provides the clerk with information for entry on to the slips

As these slips are completed they are detached from the board and passed to the cost clerk They thus act as a reminder that these jobs are then ready for complete costing A works job book is kept of each job that comes into the works In this book the following details are entered—

(1) Job No (2) Customer's order No and date (3) Date received (4) Date acknowledged (5) Name of customer (6) Price (7) Quantity (8) Drawing No (9) Description (10) Finished (X)

From this book, charts which are attached to the progress board are compiled These charts show over monthly periods the value of the load on the works, the cumulative orders and the cumulative deliveries effected The cost clerk enters these up daily

A progress board for inquiries is also used This is a single column on the progress board system which presents at a glance all the inquiries and particulars of how they are being dealt with

A very simple form of control board in a jobbing shop where it is sufficient to know that the work is roughly progressing according to plan is shown in Fig 70 In this case the dates the jobs are due to start and finish are filled in, and as the jobs progress the foreman enters the following signs according to the state of the work—

job started
half-way finished

three-quarters finished
finished
o waiting

It will be noted that only job 1024 started on time, but it got held up when three-quarters finished The usefulness of the chart might be increased by adding under the sign o the reason for the delay

A simple form of control board for the issuance of jobs in a repair shop is shown in Fig 71 It may be one-sided or two-sided as required The numbers of the machines are placed along the top, and each vertical column has four pockets The job card in the pocket A relates to the job in hand, and the card in pocket B is for the next job in order The third pocket C contains cards relating to jobs for which materials are available, and D houses cards for which the materials are not yet available This board is operated by the progress clerk, and the cards or slips may be made out in duplicate or two parts marked (1) and (2)

Let us imagine that the card in B has just been placed in pocket A The progress clerk takes the top card out of pocket C, makes out the requisition for material and sends it with the card to the foreman or group leader When the materials are alongside the machine one part of the card is sent back to the progress man, who places it in pocket B When the job in hand is completed the job card is brought to the progress clerk, who clocks it off, the card in pocket B being then clocked on

Although in a small organization a minimum of paper work is desirable, the progress clerk can assist the foreman in a number of other ways, for example, by filling in the job ticket numbers on a simple form like the following—

Order No Time due

Particulars	Job Tickets		Machine	Worker
	No	Description		

Works Order No	February						
	1	4	8	11	15	18	
1021	start o	o			due		
1022		start o	o	o		due	
1023		start o					
1024		start			due o	o	
1025							

FIG 70 SIMPLE CONTROL BOARD

PRESS SHOP							
M/C No 1	M/C No 2	M/C No 3	M/C No 4	M/C No 5			
A	☐						
B	☐						
C	☐						
D	☐						

FIG 71 A SIMPLE BOARD FOR A JOBBING OR REPAIR SHOP

The progress board may be more extensive than the simple one shown in Fig 71, it may be twice the depth, and a number of different types of machines may be represented on it It is, of course, a control of the order of jobs, but not of the time of the jobs The progress clerk may, however, keep a sheet or form under the headings of

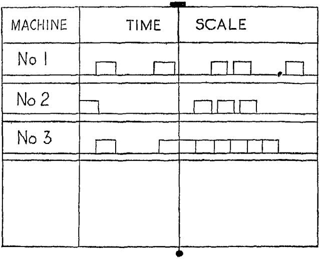


Fig 72 Work Control Board

Machine Number, Job in Hand, Time Started, Time Allowed, Time Finished, and Follow-up Job This will enable him to keep a check on whether the work is going through as desired Planned work per machine depends largely, however, on whether the operation times can be accurately estimated

An attempt may be made to connect up such a control board as mentioned above by having a time scale along the top, the machine numbers appearing in the first vertical column (see Fig 72) A shallow rack for each machine contains the job cards, which are placed in a position to indicate when the work should commence A plumb-line

Customer	Order No	Date	Particulars	Operations					Sub Assembly				Assembly			Dispatch
				Transfer Plates	Printing	Stamping	Trimming	Beading or Swaging	Rolling	Hooking	Seaming	Soldering	Wiring	Lidding	Packing	
Smith & Co, London	1001	15/7	500 gross Lids × 123A	6 7 18/7	S White Gold Blue 26/7	D 27/7		B 27/7	I 28/7					✓ 29/7	✓ 29/7	Commence 3/8
			Bodies × 123		Gold	K	✓		O						✓	
Legend Dates are planned dates				Nos. 6 & 7 Transfer Plates	S = solid colour	D = dome K = recess		B = Bead	I = Turn in O = Turn out					Fit lids and bodies together		

FIG 73 PROGRESS SHEET FOR METAL-BOX MAKING

may be moved along to the time at which the board is being examined, and any machine which shows two cards to the left of the plumb-line is obviously behind schedule

CONTROL IN A TIN-BOX WORKS

Fig 73 shows a progress card suitable for use in metal-box making The order refers to small tins, but all the columns may be in use for operations on large tins The progress clerk will put the work in hand on the dates indicated, inserting the dates in red ink on the right-hand side of the columns when the operations are actually carried out Thus the progress sheet will show at a glance what operations are to be done and when, also if they have been carried out in accordance with the schedule The insertion of the planned dates naturally depends on a knowledge of the work before the machines, other delivery commitments, and so on

CONTROL IN A GLASS WORKS

The actual procedure in a glass works will now be given as an illustration of progress control On the receipt of orders the amount of work involved is expressed in man-hours and the labour cost calculated In the Progress Control Book each process is allotted orders to the extent of its daily capacity For each order a perforated ticket is made out, one perforated section for each process These tickets accompany the materials in their journey through the shops After the first process the work is inspected, and the bottom of the ticket torn off and returned to the control office by means of the pneumatic-tube system installed throughout the works The fact that the process is completed is then recorded in the Progress Control Book If the inspector's decision is to reject the part, a new perforated ticket is issued, but this time it is red in colour to denote that the work is behind schedule In a similar way, the remaining portions of the ticket relating to a given piece of work continue to come in until the product arrives at the dispatching department It will be seen that the Progress Control Book shows the position at a glance with regard to every order The system referred to also involves the use of a Promise Board, which is a simple but effective device having the headings shown in Fig 74

Across the board are stretched a number of strings or wires on which small tickets referring to each order are hung in the appropriate column to show which day the work

Overdue	This Week						Next Week						Ready or Wait
	M	Tu	W	Th	F	S	M	Tu	W	Th	F	S	

FIG 74 DELIVERY PROMISE BOARD

is going through Obviously it is useless to have more cards under a given date than the machine-hours capacity available It thus gives a comprehensive picture of the loading of the plant and forms the basis of promises for future deliveries Cards can be moved either to give priority or to make way for more urgent work (corresponding to red tickets, for example)

PROGRESS CONTROL IN AN ENGINEERING WORKS

In an engineering works engaged in batch or lot production the following system has proved effective and permits visual indication of the state of any order The system is, of course, based on orderly method throughout, including location of stores, drawings, jigs and fixtures, etc To understand how the control board works, reference must first be made to material sheets and work tickets The former are issued by the drawing office in quadruplicate, one being for the cost office Three copies go to the progress office, where the weights are entered From there a work ticket is issued for each machining operation, showing set-up time, working time and rates If the materials are ready, the tickets are released to the boy in charge of the progress board This is about fifteen yards long, having a top portion divided into monthly and then weekly sections into which small slips showing the order number, date of ordering and due date are inserted in the order the jobs fall due, so that the general delivery position is seen at a glance

The main portion of the board consists of horizontal racks into which flat tin containers are slid, having on the face a card the colour of which indicates the urgency of the order, and which contain all the work tickets appertaining thereto Each coloured card has a summary of the operations involved The first work ticket is taken by the boy referred to and placed in the job rack, of which one side only is accessible to him The rack is subdivided horizontally into a number of endless belts, which accommodate the work tickets, and the lad places the ticket in the belt corresponding to the group number of the machines on which the work will be done The other side of the job rack is accessible to girls whose duty it is to issue the work tickets to the machinists, the arrangement being such that a girl is bound to take the first ticket which appears on the endless belt A workman states his group number and is handed the first work ticket with a job card which the girl clocks on and off in the usual way The job card and the work ticket go to the inspector and, if correct, the ticket is passed back to the lad in charge of the progress board, who can now liberate the next work ticket on the order, striking off the completed operation on the card in front of the container In marking this card a suitable series of symbols shortens the clerical work

In due course, all the operations are crossed through and all the completed work tickets are back in the container It will be seen that this progress system permits immediate visual ascertainment of the position as regards any of the jobs in the works, of which several hundred are going through at the same time, i e if any job is up to schedule and, if not, how much behind and how the delivery date will be affected The colour scheme concentrates attention where it is most needed, and the top of the board gives a picture of broken promises outstanding and the load ahead of the shops

PROGRESSING TOOL EQUIPMENT

Tool room progress work is essential to prevent rushing and congestion of work in obtaining jigs and fixtures, special tools and cutters

An efficient progress system for controlling the manufacture or repair of jigs, tools, fixtures, etc , is of great importance Delay and expense in the production shops will obviously be caused if the least urgent tools are put through first, in fact, a state bordering on chaos will result unless a proper planning and progress system ensures that the tools will be ready with an ample time margin before production is scheduled

The essential steps in planning tool production are—

1 Issue of blue prints
2 Requisition of materials
3 Planning the operations
4 Planning the assembly, inspection, and adjustment

The time allowed for finishing a jig or fixture will depend, of course, on the size of the tool-room staff, but the dates having been fixed, the tool-room foreman can be kept to them by ordinary progress methods, as inspection of the chart shows at once the position of each order, and enables the staff to keep track of details and where any delay is taking place.

When an order is issued to the tool room with blue prints, the required date of issue of the tool to the shops should be stated A convenient type of progress card is shown on page 270

Tool No		Description			Date Ordered		Date Required					
Part No	Description	Material Required	Requisition Note	Ex Stock	Bought Out	Date Received	Operations					
I							(T_1)	(T_2)	(D_1)	(M_1)	(G_1)	○
2							○	○	○	○	○	○
3							○	○	○	○	○	○
4							○	○	○	○	○	○

Fig 75 Tool Progress Card

All operations are specified and indicated by symbols in the circles, the time allowed being also given Working backwards from the due date, the latest permissible time to start the operations on each part will be ascertained Planning involves requisitioning the materials, making out the job cards and plotting the machine-hour load When work has started and job cards are returned from the operatives, a stroke is put through the corresponding operation circle, so that the card shows at a glance how far each part is completed

The machine load chart which is, of course, also useful to enable the tool room to make delivery promises, may be drawn up as shown on page 272

The machine hours of the various operations are totalled and plotted as bar charts bearing in mind that each week represents 47 hours multiplied by the number of machines Further work for any given week may be plotted as a second line, against which is put the number of machines which must work a second shift, for example, 3 centre lathes must work night shift during the week ending 7th January

When tools are bought out, it is important to ensure that the delivery date of each item will fit in with the sequence of operations, for example, it will serve no useful purpose to receive the final operation tools before the first operation tools are ready A simple form shown on page 273 will assist the purchaser or progress chaser to obtain delivery in the correct sequence

PRODUCTION CONTROL BY WORKS DOCUMENTS

In spite of the advantage of control boards in giving a bird's-eye picture of the progress of production, they are not, of course, absolutely essential Use and custom render progress clerks extremely speedy at reading records, and the following is an illustration of the principle referred to above of letting the manufacturing documents of instruction serve as the progress records The procedure

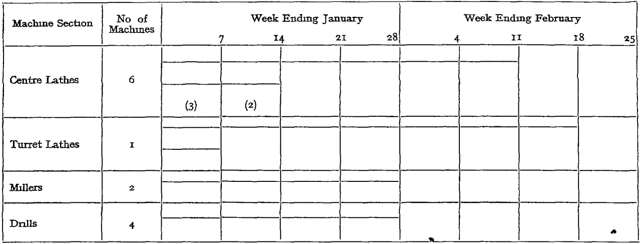


FIG 76 MACHINE LOAD CHART

Operation No	Tool No	Description	Inquiry Posted	Quotation Received	Date Ordered	Ordered From	Order No	Delivery Date	Revised Date	Received	Report No	Returned	Issued to Stores
1	101 102	Drill Jig Depth Gauge											
2	103	Milling Jig											
3	104 105	Drill Jig Plug Gauge											
4	106	Facing Cutter											
5	107	Screw Plug Gauge											

FIG 77 TOOL PURCHASE PROGRESS CHART

again refers to an engineering works on batch or lot production

Job orders are issued to cover each operation, giving particulars, times and rates Four copies are made out in the progress office, each of different colour and having its own lay-out, so to speak One is retained and three are sent to the foreman in whose section the work is to be done The first copy gives full particulars of the materials required and the foreman sends it to the stores When the materials are ready the storekeeper signs and sends it back to the foreman When the latter is ready to start work he sends the copy back again The transport man initials to the effect that he has duly received the goods, and the storekeeper sends the copy to the progress department, its presence on the file of this department showing that the work has been started The second copy of the job order gives particulars of the tools, jigs, gauges, etc , and the foreman sends it to the tool store The procedure is the same as above, except that when the foreman sends the tools back he receives the order cancelled The third copy serves as a form on which the operator books his time It is issued in exchange for a completed order The shop clerk clocks it on and off and sends it to the progress department The latter attaches the fourth copy and sends them both to the inspection department If the work is satisfactory the inspector signs the third copy and sends it back to the progress office The work and the fourth copy are sent to the progress or finished store as the case may be, and the storeman endorses the copy and sends it back to the progress office It will be noted that stores-issue notes and departmental notes are dispensed with

NON-TECHNICAL USES

Progress work is concerned with more than the technical side of production In our suggested organization chart in Chapter I, we put the labour department under the progress manager because it is as essential to get the workers into the shop as the work As an illustration, it may be necessary for the progress man to keep a reserve of labour available for manning machine groups which are not keeping pace with the master schedule A further use of progress records is the calculation of actual costs to determine their coincidence with or deviation from those budgeted

Progress control procedure is equally applicable in the organization of office work As an example, we may refer to the use of progress cards in connection with the receipt of inquiries and invitations to tender Before a quotation is sent, drawings may have to be prepared, material specifications decided, labour cost estimated and completed with overhead charges, agents may have to be advised, and so on For some reason or other, the inquiry may get held up in one department and the tender be sent in too late and not be considered Some firms therefore prepare progress cards for each inquiry, the departments through which it has to pass being indicated in vertical columns At the top of the card is the time scale calibrated in days from the receipt of the inquiry Coloured tabs may be clipped on to the tops of the cards indicating when the documents should be out of a particular department and passed on to the next The office progress clerk looks through the cards every morning, removes those which are not up to schedule and, after making appropriate inquiries, brings them to the attention of the sales manager

Alternatively the progress card may be printed on the outside of an envelope which contains the documents relative to the inquiry

CONTROL OF INTERNAL TRANSPORT

In a firm having more than one production department the progress manager should be in control of the internal transport system of a works so as to co-ordinate it in the interests of the firm as a whole The procedure is frequently followed of placing the foreman in charge of the transport in his own shop The primary duty of the foreman, however, is production, and provided he can get work moved when he wishes, he will not worry if the next department is waiting for work or the means of transport is standing idle a large portion of its time The transport system is essentially a conveyor in relation to the works lay-out, and control by foremen leaves loose ends in each department It is the duty of the progress department to follow production so that jobs are completed on time and moved the next step, whether that be the inspection department or the following production department Transport is the physical aspect of progress work and it seems logical that the department should authorize and control movement of work, in fact, if the department does not exercise this control, its paper work will break down Not only does it impart balance to the transport system, but there is better expectation of its being used with optimum efficiency and incidentally increasing the efficiency of the foremen

Economics of Quality of Work

Apart from financial reasons, all customers or consumers always want quality, which, read in a wide sense, means excellence of an article for the purpose in view Standards and specifications in themselves tend towards a more satisfactory and consistent quality, but, in spite of this, departure from the desired quality may arise from accidental manufacturing errors or the human factor, e g inexperienced or careless workers Competitive buying tends to reduce prices and therefore quality, and, however complete a specification may be, the need of inspection will still remain High quality invariably gives better service and longer life, but low initial cost is a strong attraction It is always possible, however, to make an article worse and therefore cheaper than somebody else, and those to whom a reasonably high standard of quality and reliability is essential realize that this cannot be ensured without adequate inspection and test

Economics of Accuracy

Commercially, there is no such thing as exactly to size In this sense it is impossible to reproduce a dimension with absolute accuracy Precision is measured by the amount of variation between alleged duplicate parts It is necessary to fix the permissible variation for different types of work Tolerance is the difference in dimensions prescribed in order to allow for unavoidable imperfections in workmanship Obviously, the absolute limits are the maximum and minimum sizes of each part between which it will function properly In settling working limits, the work must be planned from the economic point of view or in other words they must be established with reference to the expense of manufacture From the commercial point of view, the limits must be fixed as wide apart as possible consistent with the production of an article which will fill the requirements

Taking as an example the question of fits, of which there are four usual classes, force, driving, push, and running, standard allowances are prescribed for different qualities of work (Newall Standard or B S running fits) In fixing allowances, due regard must be given not only to practical considerations (e g working conditions, temperature, and lubricating conditions), but also to the cost of production so as not to prescribe unnecessarily accurate work for the purpose in view

Economics of Gauging or Checking Work

In workshop practice gauges are used to ensure that any given dimension is within the tolerance laid down for the class of work to be produced Their use depends on the amount of production, but obviously spoiled parts must be eliminated as quickly as possible, and in modern commercial work efficient means of gauging are imperative There are many kinds of gauges in use, e g —

1 For absolute measurements—scales, verniers, micrometers, comparators

2 Single-purpose gauges—gap, ring, plug, concentricity, ring thread and plug thread gauges, templets, hole location gauges

3 Mechanical gauges—amplifying gauges, expanding plug gauges, uniformity of motion indicators, dial indicators for contours or profiles

4 Optical gauges—magnifying, projecting

Gauging may be largely an automatic procedure involving the use of go and not-go gauges of the ring, plug or gap type This is well within the capacity of female labour Handling time can be saved by fixing the gauges in adjustable bench clamps Direct reading gauges are to be recommended

A thorough-going system of gauging is costly, but it is usually found that a liberal expenditure is cheapest in the long run In interchangeable manufacture it is, of course, essential Usually the simpler the gauge, the more efficient it is as well as the less costly, but steps should be taken to overcome the necessity of multiplicity of gauges Two or more individual snap gauges may be replaced by a stepped gauge Adjustable gauges overcome throw-outs due to wear Wherever possible, gauges should be such that they will function without the work being removed from the machine

The accuracy of the gauges is important It may depend on the manufacturing tolerances or may have to be dead to size Suppose, for example, it is necessary to have identical gauges in different shops The limits of inspection gauges will be within the limits of working gauges It may or may not be necessary to have master gauges Primary standards (gauge blocks) are expensive and it may be sufficient to send secondary standards for periodic check

ECONOMICS OF INSPECTION OR CONTROL OF QUALITY

The object of inspection is the attainment and maintenance of standards and specifications Not only does a firm's reputation accompany its products, but defects and failures are costly Defects may arise from unsatisfactory design, inferior materials, improper mechanical or other treatment, or careless assembly The role of inspection in an economic production scheme may be likened to a multistage sieve or screen On to the top screen the various raw materials pass, those up to standard passing through, the rejected oversize being the defective materials The second screen is the part or component inspection, so that defective parts do not reach assembly The third screen eliminates unsatisfactory assemblies, and the fourth or product inspection ensures that only units that are 100 per cent right reach the consumer In other words, material inspection eliminates manufacturing troubles and avoids the expense of wasted materials and of time spent in machining and fabricating them, component inspection makes assembly easier and more efficient, product inspection ensures correct functioning and safeguards the firm's reputation

MATERIALS INSPECTION

Materials pass through the inspection department on their way to the stores As it is desirable to reject faulty material or work at the earliest possible stage, one of the worst forms of waste is inefficient inspection at this stage owing to the losses which it may entail at subsequent stages of manufacture Materials are now usually purchased to specifications, and they must be examined in the light of these before certification The inspection depends on the work, the materials or the function the components made from them have to perform, and includes the following counting, measurement, chemical analysis, tests of mechanical, physical, electrical, and thermal properties, optical or X-ray examination, endurance or life tests and trade tests If the "raw" materials are finished parts, they must be correct in every detail and may have to be specially tested, e g undergo pressure tests or performance tests

With the increase of automatic and semi-automatic machinery, the importance of efficient material inspection has increased, as with a high output volume serious losses may quickly arise As the inspection department must provide the purchasing department with guidance in its commercial work, certificates of rejection must always state the reasons and acceptance certificates the test results Mere "O K" notes do not permit the most to be made of inspection reports

Tool inspection commences in the tool room It is of the greatest importance, for if the tools are not correct the work will be inaccurate Apart from checking dimensions some components may be run off and inspected before the tool is sent to the stores This subject was discussed in Chapter V

INSPECTION DURING MANUFACTURE

Inspection during manufacture involves not only inspection of machining processes, but also equipment and tool inspection, inspection of assembly and erection, and final tests, which may include running performance, consumption and acceptance tests Adequate inspection during production eliminates hand work and fitting during assembly The system of inspection adopted must be based on the requirements of the factory and product

In the manufacture of parts or components the question of floor versus centralized inspection arises, as to which permits the more rapid and efficient handling of the work in the shop. The question is important as the throughput of shops depends on adopting the right amount and type of inspection It is impossible to draw any hard-and-fast rule, but centralized inspection sometimes leads to considerable waste of time, though it depends on the lay-out of the factory, and this system is probably the best for a small works It has the advantage of thoroughness and is necessary where every individual part requires a mark of acceptance as in aircraft work A centralized inspector can also keep records of the causes of rejection more readily Faults and defects should be detected immediately they arise, but, in any case, there is a greater saving in detecting faults while the operation is in progress than after a given batch is finished With the growth of repetition work the importance of early detection of errors has been increased, and it is now a general practice not only to inspect the first few pieces from a set-up, but to keep an eye more or less continuously on the work coming through This random selection is to ensure that the set-up has been maintained. With automatic machinery, as soon as an inspector notices irregularities a rectification order is put through The inspectors may be located between machines in the flow line of production In heavy engineering floor inspection is necessary for practical reasons

We have referred above to the basic importance of precision in interchangeable manufacture For interchangeability drawings must be dimensioned from working or register points as the tolerances are closely controlled The smaller the tolerances the more frequent the necessity for inspection

ORGANIZATION AND STAFF

A feature of industrial development is the rising status of the inspection department We have seen the multiplicity of duties to which inspection extends, e g control of standards of materials, during manufacture, assembly, testing, salvage, heat treatment, jigs, tools and fixtures In a large works the post of chief inspector is obviously a responsible one, though, in fact, the inspector may have greater powers of discretion in a small works than a large one

It is important that the department be independent, but it must be effectively co-ordinated with the rest of the works and the sales department so that the inspectors may know how their job relates to the other phases of the firm's activities No one but the inspection department must have the authority to pass or reject materials or jobs If the factory can overrule these decisions difficulties may develop later Although in practice the inspectors may frequently be responsible to the works manager, it is easy to imagine that the latter, being anxious to keep up production at all costs, might tend to lower the standards, and the reliability and service of the product in the hands of customers might be prejudiced The question of the responsibility of the chief inspector is a thorny one, but it is at least worthy of notice that in some firms the above difficulty is so far appreciated that he is responsible to the general manager or the progress manager or even the secretary of the company In any case, if the decision of the chief inspector is to be overruled it should only be after consultation between the managers concerned with the product

The efficiency of the department depends on the employment of suitably qualified labour An essential characteristic is reliability The labour may vary from girls (e g for "go" or "not-go" gauging) to qualified engineers, according to the type of work In engineering inspection, the inspection staff usually needs a special training and should be chosen from types having versatility, keenness, and quickness at work and a sense of anticipation It should be capable of making concise and accurate reports which set forth the essential particulars at a glance, with adequate reasons for decisions

COMMERCIAL BACKGROUND OF INSPECTION

The cost of inspection staff and equipment is an expense which is ultimately borne by the consumer In spite of its importance, this overhead must be kept to the minimum consistent with maintaining the quality of the product

How, when, and where, and to what degree to inspect must be laid down by the management, in order to ensure that the standard of inspection is in accordance with the quality and quantity of work required

Only such inspection and tests as are absolutely necessary to ensure efficiency and safety should be carried out and done in the most economical manner In deciding whether an inspection operation is necessary, a point to bear in mind is whether its omission will make possible rejection at a later stage or prove a source of failure in service It may be possible to establish control of workmanship at strategic points and eliminate it at others The value of the test or inspection must be considered in relation to its effect on the price of the product Economy in inspection may possibly be effected by considering whether 100 per cent examination is necessary or can be replaced by percentage testing or periodic selection of samples

The cost of inspection must be judged on its use to the higher control The amount of inspection must be scientifically determined by what is best for the class and amount of work in question In other words, its cost must be reasonable in all the circumstances judged against the commercial background Setting the right standard or degree of inspection, in fact, always involves a compromise between the opposed views of the sales department on the one hand and the production and progress departments on the other

The costs of inspection demand as much consideration as actual manufacturing methods and must be kept within predetermined limits One of the best means to control an expense is to bring it at regular intervals for examination and justification The wages cost of inspection should therefore be segregated and expressed as a percentage cost per product This may be done for each department as follows—

WEEK ENDING

Department	Inspection Wages	Number of Products	Inspection Cost per Product	Works Cost of Products	$\frac{\text{Inspection Cost}}{\text{Works Cost}}$
A					
B					
C					
D					
Total					

A stationary inspector is a constant cost, but a roving inspector may have to record his time

Comparative costs stimulate questions and will lead to the examination of each stage of inspection to determine its elimination or retention

Inspectors should have a good knowledge of the use of what they are inspecting so as to take an economic view of the job with regard to its function Inspection is something more than looking for defects and bad work, in one sense, its efficiency is inverse to the number of rejects An inspector should be able to differentiate between accidental manufacturing errors and poor-quality work, between rushed work and the results of machines or tools out of order

In all quantity-produced articles there will be minute deviations from the standards laid down which do not affect the ultimate performance The inspectors must appreciate that the dangers of arbitrary or over-scrupulous inspection may be as great as those of inefficiency Time must not be wasted on points that do not warrant it, it is, for example, uneconomical to insist on closer tolerances than are essential, but when rigid inspection is necessary the parts must not be glanced over

Inspection operations and instructions should be included in the manufacturing sequence sheet The inspection schedule should state the component's name and part number and the number of the parts with which it has to be assembled, also its function, what has to be checked, the permissible tolerances, the method of checking, the gauges to be used for each operation, the percentage of inspection, and other necessary instructions

Inspection should have an accelerating not a clogging effect on production, it is intended to be preventive rather than corrective, co-operating with the foremen in every practical way for the achievement of specifications The waste and delay through retarded delivery caused by an over-conscientious inspection may rise to unbelievable heights Inspecting does not mean mere arresting of work which is wrong, it should involve saving, not rejecting, a job if any practical means is available for effecting a remedy The inspector must have a thorough knowledge of rectification, re-treating, and repairs by welding, deposition, etc He must co-operate fully with the salvage department with regard to spoiled work and maintain scrap at a minimum

INSPECTION RECORDS

The utility of the inspection department depends a great deal on the records it provides It should get together and tabulate the nature and percentage of defects so that the facts and statistics may be used by the management in the interests and service of the firm The proper handling of inspection results may provide many useful suggestions and improvements by locating production troubles, lack of balance, or actual wastage Besides showing up bad or slow work, the department's conclusions, reasons and recommendations will enable remedies to be evolved, and may indicate that a revision of existing standards is necessary

INSPECTION OTHER THAN IN MANUFACTURING

Inspection during production is not the only branch of general engineering inspection In addition, we have inspection by the following—

1 Government departments and municipalities Inspection, carried out by permanent staffs, is usually keen and may be severe Over-rigid specifications sometimes result in high costs

2 Insurance companies Inspection is usually very efficient, the companies having done a great deal to increase reliability in all branches of engineering

3 Consulting engineers and architects, more particularly concerned with buildings, bridgework, and other large engineering schemes

4 Inspection specialists, usually employed when the

amount of a firm's purchases does not warrant the employment of a permanent staff The status of professional inspectors was raised by the formation in 1919 of the Institution of Engineering Inspection Although these professional inspectors are employed by the purchaser, they must inspire confidence in the manufacturers and know the tricks of the trade

The economic justification of organized engineering inspection from the point of view of the purchaser is that he secures the maximum efficiency in the expenditure of his capital Apart from this, a single serious accident may outweigh many times the cost of inspection, e g in the failure of overspeed governors of steam or water turbines Prices may be so cut under competition that materials and workmanship suffer, and the greater the margin between the average and the accepted tender the greater is the need for inspection Other features increasing this need are the remoteness of the destination of the plant from the place of manufacture, the increase in the indirect cost due to a breakdown, and the ratio of the cost of the specific piece of plant to the total capital expenditure Engineering inspection to secure a plant adequate for its duties must be considered

An economic problem arises in the case of a large concern which purchases plant and materials from all parts of the country, viz whether to employ professional inspectors or its own staff, and whether the latter should be resident or travelling If there is sufficient work the staff is justified and centralization also secures unity of attitude

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CHAPTER VIII

PURCHASING

As materials usually constitute the major portion of prime costs there is no need to emphasize the importance of this function of a manufacturing business. The requisite of minimum overall cost of materials involves much more than buying at the lowest price. Consideration must be given to the fabricating cost and avoidance of work on defective material, avoidance of loss of interest on money tied up in stores, the prevention of accumulation of obsolete stocks, the avoidance of dislocation of schedules through lack of materials and other factors before any judgment can be passed on the overall economy of the firm's policy with regard to materials.

Though some industries depend on seasonal supplies and in others hand-to-mouth buying may be advantageous, it is usually best to take a long view with regard to the purchasing and storing of materials. Even if the purchaser has obtained materials of the required composition and properties to meet the requirements of the production department with regard to working up, and in the right quantities for the budgeted output, there are still opportunities and loop-holes for waste without adequate stores control as regards the receipt, the physical handling and storing and the issue of materials to the shops. All materials represent invested money, and the control must include the monetary point of view, not only as regards ascertaining the materials cost of each job but also securing the optimum investment of the firm's funds in this direction.

The criterion of the efficient purchasing of direct materials is the overall price including the cost of processing, and of indirect materials the cost per unit of service, though there is sometimes difficulty in establishing means of measuring the real elements of the service The total cost of materials includes the cost to procure (price plus transport), the cost to possess (interest and insurance), and the cost to process In the case of machinery the last factor is replaced by the cost of operating

IMPORTANCE OF THE PURCHASING DEPARTMENT

One of the first acts, if not the first of all, of a manufacturing business is to purchase materials Obviously, this has to be done before men can be employed to work them up As we have noted, a large proportion of a firm's expenditure flows through this channel, so that purchasing must be as efficient as production and sales Good work in the shops may be nullified by bad purchasing, whilst, on the other hand, profits may be largely due to careful and efficient buying It should be remembered, however, that good purchasing saves money, and does not make it

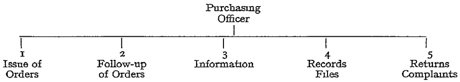
Buying is not an isolated function of the firm, but an essential part of the organization and must be carefully co-ordinated with the other departments The purchaser must be in touch with the practical operations in the shops and understand the needs of the planning department The average buyer is not an engineer, but he has to interpret the requirements of engineers and ensure technical suitability of the material He is a vital factor in the progress work of the firm and in the first stages the production schedule is dependent on him The company which is willing to spend comparatively little extra money on a man who has technical knowledge of the goods with which he deals as well as commercial knowledge, may expect to be amply repaid Understanding the view-point of the works, he will not require to be told that the material with the lowest first cost is not necessarily the cheapest In fact, the frequent tragic results of cheapness need no emphasis, as previously indicated, there is hardly anything in the world which men cannot make a little worse and sell a little cheaper The purchaser is not, in fact, so much concerned with minimum price as with maximum value

DUTIES OF THE PURCHASING OR SUPPLY DEPARTMENT

Material planning involves the supply of special materials and control of the stock of raw material and of finished parts or products

It is the duty of the purchasing department to provide adequate supplies of suitable materials at prices which are most economic in all the circumstances The closer the association with the factory the less likely is cheapness to develop into a fetish He must, however, understand the economies securable from the use of standard materials and parts The purchaser should be on the production committee, in fact, it is difficult to think of this committee functioning without him as he is an important co-ordinating agency between production and finance Although he will endeavour to ensure the fitness of the materials from the shops' point of view, he must not be given cast-iron instructions but must consider it his duty to suggest alternatives as regards other materials offered or other sources of supply He must check quantities or at least be responsible therefor, and ensure that the proper inspection and tests are made It is the purchaser's duty to ensure that delivery is given at the due date stated in his orders, so that he is responsible for follow-up without prompting He must keep proper records of prices, handle all invoices and discounts and co-operate as necessary with the financial department He is also responsible with regard to returnables to suppliers, on which, without adequate attention, money is easily lost The question of disposal of scrap and waste is also his concern He must know when and where to buy From a practical knowledge of the "availability" of materials he must ensure a steady supply if such is required or at least sufficient quantities to meet demands, especially with regard to any penalty or bonus orders his firm has taken

SUMMARIZED FUNCTIONS OF THE PURCHASING DEPT



Function 1	Involves the purchase of correct material as and when required
Function 2	This work is not finished until the material is in the hands of the department requiring it, and delivered at the right time
Function 3	Information must be available on sources of supply, prices, deliveries market conditions, and so on.
Function 4	Documents such as requisitions, inquiries advice notes completed order etc , must be available for instant consultation
Function 5	The department is responsible for negotiations with suppliers concerning material returned whatever the reasons .

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AUTHORITY OF THE PURCHASER

In a large firm the purchasing officer may deal himself with such matters as negotiation of contracts, disputes with suppliers, administrative difficulties and interviewing callers, and delegate more routine matters to his assistants

The qualifications of a purchasing officer may be summarized as follows—

1 Organizing ability
2 Knowledge of purchasing technique
3 Foresight and judgement
4 Ability to negotiate
5 A practical knowledge of the industry
6 Knowledge of the supplies of materials his firm uses
7. Knowledge of economic conditions

The question of the responsibility of the purchaser has already been raised and, of course, responsibility and authority go together The authority of the purchaser frequently proves, however, a debatable subject He must, of course, be responsible for all expenditure, that is, completely control the buying activities, but it is obvious that he cannot be allowed to buy without consulting the technical experts and engineers who have subsequently to use the materials Should the purchaser, therefore, be under the control of the works? It is suggested that this should not be the case Production is not the only or even the most important function of the business Questions of finance and policy are paramount

It is now generally conceded that the purchasing or supply manager must be accountable to the chief executive of the concern, although he is, of course, required to work in close contact with the works manager and co-operate with the design, progress, inspection, sales and advertising departments The vital point is to leave the buyer a free hand, e g with regard to standard materials, with such measure of financial control as may be necessary in the circumstances In any case, the extent of the buyer's responsibilities should be made clear to him He must work in gear with the other departments of the firm exercising keenness without encroachment, zeal without jealousy

BUYER CRAFT

The correct choice of materials is largely the job of the chief engineer and draughtsman, but when, where and how to buy and at what price are the purchaser's concern For the present purpose we may neglect products the selling price of which does not depend on the manufacturing cost Most engineering work is still obtained on a competitive basis, and we have seen that effective buying is an important factor in commercial success Buyer craft, buying acumen, or flair for purchasing is not common to all men, and those who have it need to be trained and developed like any other executive, particularly in engineering firms where their effectiveness is largely dependent on their ability to co-operate with technical men

It might be suggested that with the recent growth of ring prices there is little or no scope for buying acumen, but we have seen that low first cost is only one constituent of efficient purchasing The buyer can do much more than purchase supplies to specification He must see that the materials are the most suitable from his firm's point of view and keep a sharp look-out for something better or for substitutes to reduce manufacturing costs, remembering that it is the final cost which counts, not the initial cost Co-operation with the firm's research department will keep him conversant with new ideas and be a guide as to what to look for He may request the department for reports on the materials used by the firm as to whether the quality may safely be lowered or alternative materials be used The purchaser is in a position to learn a good deal from the other firms' representatives who call upon him They are able to supply him with valuable information as to why and how the results they claim may be achieved, and sooner or later the purchaser will hear of something which his own shops may adopt with advantage He may, in fact, be a valuable source of information on sales and economic and technical matters which may be secured from contacts with the business world

He may learn of materials which give a longer life to tools or need decreased machining time, or of machines having higher productivity or lower maintenance charges By encouraging representatives, but without letting them waste his time, he will be kept in touch with advances in the arts He can then search out the facts and bring them to the notice of the factory in accordance with their merits

As it is part of the buyer's job to seek out dependableness in suppliers, he must be dependable and reliable himself Controversies are of no use to the purchaser's firm and must be avoided The purchaser must appreciate that interruption of smooth flow in the shops may cost the firm many times more than paying a little more to get the goods on hand when needed It is impossible to eliminate the risk of non-delivery, but the personality of the purchaser is probably the chief factor in ensuring that supplies are on hand when they are needed and preventing any discouraging position in the shops In all possible ways the time of the factory must be conserved

In order to know when to buy most advantageously the purchaser must watch the movements of the markets Market information must be tabulated and graphed so that he may make full use of the trends and fluctuations and turn the prevailing conditions to his advantage from the point of view of both price and delivery The purchaser applies his knowledge of the firm's probable as well as present needs, though there is rarely anything of the nature of speculative buying of engineering products In fluctuating markets, however, where forward purchasing may or may not be advantageous, the experienced and well-informed buyer scores heavily If the trend of prices is definitely upwards, contracts may be placed for a longer time ahead than usual or renewed before they have completely run out If the price trend is downwards, the buyer may mainly be concerned with filling current needs with preference to vendors who are able to give best delivery, and machinery may only be bought if it can be used promptly Assurance of supplies to large engineering concerns is so important that orders can only be placed with firms having adequate facilities capable of producing materials meeting exacting shop requirements, so that, in any case, the contract system is not likely to be departed from The question of reciprocity is often an important feature in purchasing policy, although some authorities are emphatically against its limiting the purchaser's choice of suppliers The buyer should give all suppliers an equal chance and should make his choice with knowledge of their plant and machine capacity, their financial situation, technical ability, delivery reputation, transport distances, and so on

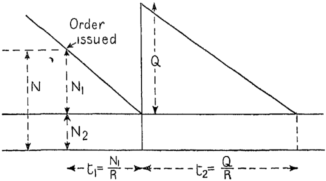

FIG 78 OPTIMUM SIZE OF ORDER

Planning of material flow requires careful control in respect of (1) supply of special materials, (2) stock of standard raw materials, (3) stock of finished parts The quantity of raw materials purchased must be accurately related to the quantities of finished goods produced

The purchaser must know the cost to the firm of performing the purchasing function, including losses due to errors and delays, and the cost of administration of his department He must not only keep accurate record of the money he is expending, but know its rate of turnover and how much is invested in materials on hand and in process and the amount required He must appreciate the cost of carrying stocks, when there will be less probability of over-stocking or of stores becoming obsolete Slow-moving stocks may tie up money that could be used for expansion and sales propaganda He must understand that the total expense of an order includes the interest on the money locked up till manufacture is complete, and the charges entailed in handling and storing the material on the firm's premises, and that for a given rate of consumption there is an optimum size of order involving overall least-cost to the firm

In the case of companies owning more than one factory, there have been outstanding developments in recent years in centralized purchasing Although there are arguments for and against centralization, the centralized office may be expected to be more thorough and efficient in operation, although slower

FIXING LEAST-COST PURCHASE QUANTITIES

The following is a simple mathematical analysis of this problem

Let Q = the least-cost purchase quantity

C = the total cost of the order

C_1 = the cost per unit

C_2 = the purchase price per unit

S = the storage charge per square foot of floor space per year

A = the storage space per unit (square feet)

U = unit storage charge per year including overhead

t_1 = time to procure goods

t_2 = time to consume Q

I = interest rate

I_1 = total interest charge during time t_2

T = total expense from requisition till goods are placed in store

N = minimum number at which new order is issued

N_2 = number in reserve

$N_1 = N - N_2$

M = number in store on receipt of Q

M_1 = number on which interest is charged

R = rate of consumption per year

Let $\frac{N}{N_1}$ = the ratio F

Then $N = FN_1 = Ft_1R$

and $N_2 = N - N_1 = t_1R(F - 1)$

$M = Q + N_2 = Q + t_1R(F - 1)$

and $M_1 = \frac{Q}{2} + N_2 = \frac{Q}{2} + t_1R(F - 1)$

Now $t_2 = \frac{Q}{R}$

Therefore the total interest charge =

$$I_1 = M_1C_2It_2 = \left[\frac{Q}{2} + t_1R(F - 1)\right] C_2I\frac{Q}{R}$$
$$= \frac{Q^2C_2I}{2R} + Qt_1(F - 1)C_2I$$

$$U = ASt_2 = AS\frac{Q}{R}$$

Therefore the total storage charge =

$$UM = AS\frac{Q}{R}\,[Q + t_1R(F - 1)]$$
$$= \frac{AS}{R}Q^2 + Qt_1(F - 1)AS$$

Total cost of the order C

$$= T + I_1 + UM + C_2Q$$

$$= T + Q^2\left[\frac{C_2I}{2R} + \frac{AS}{R}\right] + Qt_1(F - 1)(C_2I + AS) + C_2Q$$

Let the interest factor $\frac{C_2I}{2R} = \alpha$

the storage factor $\frac{AS}{R} = \beta$

the reserve factor $t_1(F - 1)(C_2I + AS) = \gamma$

Then the total cost $C = T + Q^2(\alpha + \beta) + Q\gamma + C_2Q$

Therefore $C_1 = \frac{T}{Q} + Q(\alpha + \beta) + \gamma + C_2$

$$\frac{dC_1}{dQ} = \alpha + \beta - \frac{T}{Q^2} = 0 \text{ for a minimum}$$

$$Q^2 = \frac{T}{\alpha + \beta}$$

$$Q = \sqrt{\frac{T}{\alpha + \beta}}$$

It will be noted that in this equation the amount of reserve stock does not appear

Checking Factory Costs

A useful function of the purchaser is to put out inquiries for parts or products made by his own firm with a view to checking the efficiency of the shops Particularly in the case of work which the firm has not undertaken before, it may be useful to compare his own shop costs against the prices of outside makers If his firm's consumption of a given material or component is on the increase, a problem may arise as to whether it would not be more economical to make than to buy It might appear at first sight the better policy to obtain everything which could be purchased at a less cost than it could be made, but this is not always the case Such questions as the full loading of machines and the redistribution of overheads will decide the overall profitableness of buying versus making specific components, apart from such factors as the retention or displacement of workmen and other matters of policy

The purchaser must appreciate the value of method in buying as it will assist him in many directions, not only in securing accurate checking of quantities and adequate inspection, but in sending out the correct blue prints and specifications, in knowing who holds the requisite patterns, gauges, etc, in avoiding duplicate orders, in checking invoices, in securing the proper discounts and in avoiding penalties, and so on

PURCHASE CONTRACTS

Reference has been made to the importance of contracts for raw materials We considered the elements of the law of contracts in Book I (Chap VIII) and have referred to the tendering side of contracts in Chapter IV In this chapter we are concerned with the role of the purchaser in securing the best terms and protecting the interests of his firm

The buyer must assure himself that he has reached the optimum sources of supply It may be suggested that this is not difficult nowadays with an extensive range of trade periodicals, directories, buyers' guides, year-books and registers, but it is sometimes difficult for the buyer not to allow himself to be swayed by custom, tradition, past practice, personal acquaintance, and various wheels within wheels His sole object should be to do the best for his firm, taking the long view He should leave no stone unturned in analysing the market in which he is buying, and, at least in the case of the more important supplies, he should endeavour to visit the firms with which he is proposing to place a contract

Tender forms are to-day a definite part of any substantial inquiry The specification should make it absolutely clear what material is required and contain clauses with regard to acceptance, delivery, and liability of cancellation

Attention should be given to the legal requirements of an order The rules and conditions of the purchase should be clearly set out, together with instructions as to advice notes and invoices, deliveries, and so on

The actual terms of the contract must be scrupulously examined so that the purchaser may protect himself as regards quality and delivery, the terms of acceptance being unequivocal, and the procedure in case of rejection being clearly defined, together with the extent of the vendor's liability for replacements of material or parts subsequently found defective, the force of the guarantee to deliver at the date quoted, the terms of payment and, in fact, all points on which disputes could arise It has been said that a buyer needs a hundred eyes He should remember this before placing contracts—it is no use to his firm to think too late

PURCHASING RECORDS

The documents used in the purchasing department, such as the inquiry form and the order form, should be drawn up carefully to bring out the essentials required by the purchasing officer For example, the inquiry form should state the full description of the material, the quantity in unit of cost, the place of delivery, the method of packing, whether price is to include delivery, and so on The order form will contain this information together with price and delivery, method of marking packages, etc A standard form for communication to unsuccessful tenderers is also useful

Mechanization of the purchase office routine is not only labour saving but facilitates up-to-the-minute information A continuous form writing machine reduces handling time in making the requisite number of copies of the purchase order The essential daily supply of information differs from firm to firm, but accounting machines may be applied to give the information which a purchasing officer requires For example, orders placed and dates of deliveries, receipts against each order, balance of goods to come, issues from stock, balance of each individual item of stock, the amount of money spent in any one month, and so on

Reference has been made to the necessity for systematic organization of purchasing routine In a large department it is sometimes advantageous to sectionalize, so that a buyer becomes expert in the few commodities he handles Order and regularity result in work being handled expeditiously The purchasing personnel must be kept to the minimum capable of carrying out the work, but the analytical control of purchasing information is really a question of spending to save money If possible, standards of purchasing performance should be established, i e the expense of performing the purchasing function

Among the records which should be kept are the Consecutive Purchase Record or Buying List on either cards or the loose-leaf system, a Comparison of Quotations Record, a Delivery Progress Chart or follow-up system, and a record card for each firm with which orders are placed

At the head of each card will be the address, telephone number, telegraphic address, and representative's name for ready reference, and the columns will indicate the date and price of orders placed, the delivery and inspection and shops' reports

An inquiry file may be kept consisting of a series of numbered folders, each referring to an inquiry sent out The folders contain a copy of the inquiry, the associated correspondence, the quotations received, and the final decision

Associated with this file may be an inquiry card index, stating the material to be purchased, the department requiring it, the firms to which the inquiry is to be sent, whether they quoted or not, and so on

It is useful to have a catalogue file with a comprehensive collection of up-to-date lists and technical information Study of the technical press will allow this to be kept up to date and prevent the accumulation of useless information

Other records which obviously are useful, if not essential, include—

1 The comparison of market quotations and purchase prices

2 The total and the average value of orders over a given period

3 The average cost of handling orders or cost of purchases

4 The value of the raw material in stock compared with the value of that in production

5 The percentage of orders that need following up

6 The average buying time

7 The percentage of rush orders to normal orders

8 The hold-ups due to lack of materials

9 The number of times stock falls below minima

10 The record of failures of materials and complaints received from the shops

11 The record of the disposal of scrap

The position of stocks and contracts should be continually reviewed to examine the stocks available and to come, and how long the total stock will last

A department requiring material would make out a requisition and send to the Stores Control which, if the material is not in stock, would pass it on to the purchaser The latter would obtain all particulars from the information section before passing to the order section for issue A copy would go to the accounts department and another to the follow-up section of the purchasing department, which would keep in contact with the supplier and inform the manufacturing department of delivery promises The supplier would send in the goods, and the goods received note would have to be countersigned by the department

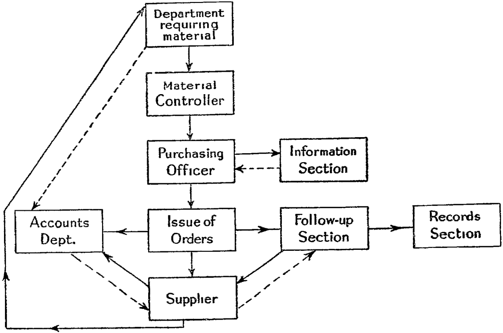

FIG 79 PURCHASING ROUTINE

requiring the material as in good condition and acceptable It would then be passed to the accounts department, so that on receipt of the supplier's invoice payment could be made These steps in purchasing routine are illustrated diagrammatically in Fig 79

In accordance with the general recommendation in this book, the total purchases should be forecast, a budget prepared, and a programme laid down The control of purchases is also helped by a classification of expenditure accounts, to which the buyer attributes each order according to its purpose The following expense accounts may be suggested as a guide—

1 Production supplies (subdivided if necessary)
2 Indirect materials (subdivided if necessary)
3 Machinery and equipment (subdivided if necessary)
4 Tools and loose plant
5 Fixtures and fittings, and
6 Electric power
7 Expenditure on buildings
8 Stationery

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CHAPTER IX

WAGES AND INCENTIVES

WE saw in Book I that the era of subsistence husbandry was succeeded by a period in which the employment of the community was specialized into single trades Later on industries were split up into a large number of separate operations This process is called the division of labour

DIVISION OF LABOUR

Although Adam Smith wrote before the Industrial Revolution, he fully appreciated the true meaning and importance of what is involved in this principle He showed that specialization is fundamental in the economic organization of industry in that the productive power of labour is thereby increased The subdivision of processes leads to greater efficiency of the workers, the improvement of tools and the invention and application of machinery The use of machinery leads to further specialization of labour, so that the effect is cumulative Every useful discovery and invention has been applied or become operative through the utilization of specialized knowledge and skill, and every increase in such specialization renders possible the further exploitation of such inventions, and facilitates new ones The history of civilization is the history of the extension of the principle of division of labour A limit to division of labour is set only by the extent of the market, which determines the scale of production We may summarize the division of labour into four main forms between one occupation and another, between one process and another, between one function and another, and between one district and another—in industrial communities districts become specialized like individuals

Advantages and Disadvantages of Specialization

The disadvantages of specialization should not be overlooked. Among them is monotony of labour, which robs the workman of all-round development, compared with the old craftsman. Intensity takes the place of extensity. It is suggested that specialization gives the workers no opportunity to develop initiative and judgment, and leads to concentration of the masses in factories and to excessive competition between workpeople. Industrial organization becomes over-sensitive, and frequent unemployment results. The workman is used as a means to an end, and labour becomes a mere commodity. On the whole, there is no doubt, however, that the advantages of specialization preponderate. We have remarked on the economy in production which it effects. As regards its effect on workpeople, it lessens the time in learning a trade, leads to increased dexterity, and better permits the utilization of aptitudes. Machinery takes over the monotonous work, increases the demand for general intelligence and adaptability, and weakens the barriers between trades, i.e. increases mobility of labour. Factory life stimulates mental activity, and depressing industrial conditions are not inherent. There is a modern tendency to decentralization, and factories are being increasingly erected in rural surroundings. Specialization induces a local market for skill, and specialized machinery leads to continuity of employment. With the progress of specialization the conditions of the workers have steadily improved also. Specialization is still increasing in certain directions—for example, in buying, advertising, and management—owing to the economies induced, but, as remarked above, it has its practical limits, just as large-scale production has. On the production side, specialization has led to standardization and interchangeability of parts, so that erection, assembling, completion, or repair of even complicated machinery can be carried out with facility at great distances from the production centre

COMPENSATION OF LABOUR

Work is something done with an ulterior motive, and compensation must be given to educe industrial effort Whilst pecuniary and non-pecuniary incentives interact, the latter are usually necessary for perseverance

The subject of wages is one of the most difficult and controversial in the whole range of economics Its vitally practical importance leads to partisanship and passionate views

It may be noted that there is really no such thing as a general rate of wages, but if money wages rise and the prices of workmen's commodities do not, there is said to be a rise in the general rate In other words, the smaller the proportion of wages spent on food the greater the prosperity On the whole there has been a considerable rise in the general rate of wages in the last hundred years, and at about the same rate in the United Kingdom, United States, and France

Wages are the nominal or money payment for the work performed Real wages refer to the value of the wages expressed in terms of things in general, i e of the goods and services which they will procure We may note the anomaly that real wages are higher during business recession than during prosperity, but real earnings, i e wages paid over a period of time, are probably lower owing to the amount of short time worked Money wages give no indication of the relative economic welfare of wage earners at different times To ascertain this it is necessary to translate money wages into real wages from a knowledge of the changes in the level of prices For the purpose in view we must use the retail prices of goods entering into working-class consumption, and not wholesale prices Variations in the working-class cost of living are given by the Ministry of Labour Index Number (See Book I, Chapter VII)

BASIC FEATURES OF WAGES

Year by year the activities of the productive forces produce the social dividend out of which all claims have to be met These claims are made up of the four categories of distributable income—rent, interest, profits, and wages The problem of distribution is concerned with determining the principles underlying the apportionment of the social dividend among these categories of income

The iron or brazen "law" of wages, as it is called, was to the effect that as population tends to increase faster than the means of subsistence, wages are never for long more than sufficient to provide the necessaries of life for a labourer and his family The demand for labour follows an economic law, but the supply of labourers does not The supply of labourers will not, however, be increased if the standard of comfort falls below a traditional value When Ricardo expounded this subsistence theory of wages, however, he had no idea of the greater productivity that would arise from science and invention

Another theory of historical interest is the wages fund theory, which largely influenced the judgment of early economists It supposed that a certain amount of capital was devoted unconditionally to the payment of labour, the fund being distributed under competition between the workmen, who must work independently of the rate of wages Unfortunately, facts are against the theory, as they have shown that there may be high wages in a new country with a rising population, and low wages in an old country with large accumulations of capital

The effect of the invention of machinery on wages may be considered Its sudden adoption will cause hardship and probably a fall in wages of the labourers whose knowledge only of the old processes causes them to be supplanted Subsequently, however, owing to the extended market and the greater skill required from labour, the wages of the machine tenders may rise

The productivity theory of wages conceives that they are paid out of a continuous stream of circulating productive capital, and depend not only on the efficiency or productivity of labour but on all factors which increase the real national income The distribution of the flow of wealth depends on the relative strengths of the bargaining parties It will be realized that capital and labour have a reciprocal demand for each other's service, but there are obviously limits to the prices at which these services will be forthcoming, the terms being determined by the combinations on either side Employers realize, of course, that low-paid labour is generally expensive on account of its inefficiency

Changes in wages are made with reference to a number of factors, e g the cost of living, state of trade, prices of products, and bargaining power of labour Settlement of the level of wages is made by negotiating machinery in most of the principal industries When a workman joins a firm his attention is directed to a printed statement setting out the working conditions agreed between the employers' federation and the trade union in the industry and referring to the overtime and nightshift rates as well as the agreed settlement of piece work and bonus prices

Wages are fixed by economic force, not economic justice, and consideration shows that wage rates are largely a reflex of demand for and supply of labour The demand for labour is indirect and largely dependent on present profits and also prospective profits The demand price is the marginal worth of labour to the employers, and depends on its marginal productivity It should be remembered that the law of substitution is always at work, i e the employer will replace labour by machinery whenever it is more remunerative to do so The supply price of labour is the wages at which different quantities of labour are forthcoming, and, of course, is connected, if only remotely, with the cost of rearing, training, and keeping workpeople It would, perhaps, be more correct to say that wages vary between a maximum of the net value of the work to the employer and a minimum which is the least an employee can take to maintain his habitual standard of living. The influence of custom on wages is greater than usually supposed. As we have seen, the standard of living plays an important part in the settlement of wages. This accounts for the greater efforts exerted in opposing a fall in wages than in endeavouring to obtain a rise. The quantity of labour employed in any industry is seen to be that of which the supply price and the marginal worth to the employers are identical.

The true theory of wages appears to include elements of both the subsistence and the productivity theory. In addition to depending on the efficiency of labour, wages also depend on the efficiency, or, rather, marginal ability, of the employers. The invention of machinery and the saving of capital increase the national dividend, and to that extent tend to raise wages.

PRIMARY PAY SYSTEMS

There are several methods of wage payments, the system adopted being dependent on the nature of the industry concerned. For the payment of basic wages time rates or piece rates are employed or a combination of both.

Under time rates the workman is paid so much per hour, day or week, the quantity of output having little or no bearing on the rates. They are generally paid where the employment is continuous, where the quality of work is of fundamental importance, or where the work cannot be standardized, as in transport, distribution and agriculture. Careful supervision is usually necessary. Pay-roll compilation is simple, but time rates contain no inspiration, and are specially irksome to a good workman if there are no annual rises. The simplicity of determining wages in advance is a point of favour with trade unions, and it is the only satisfactory method where the work does not admit of quantitative evaluation. It is estimated that over 50 per cent of industrial workers are on time work.

Under piece rates a fixed sum is paid per piece of work or unit of output, regardless of the variation in time taken, but usually with a strict regard to previously established day rates They reduce the cost of supervision and to this extent overhead expenses They simplify costing and are better from a cost accounting point of view First-class workers usually like piece rates, provided there is no price cutting or undue speeding-up and overstrain It is sometimes advanced that piece rates tend to increase quantity only at the expense of quality, that the workman is induced to rush, and that the standard of craftsmanship is lowered With highly mechanized production, however, the workman has not a great deal of control over quality, and a proper system of inspection can readily take care of the maintenance of a proper standard The difficulty of setting and revising fundamental piece rates is often of a high order, but by an enlightened understanding between management and workers this may be overcome From a labour point of view objections have been advanced that piece rates tend to produce unemployment by heightened production in an inelastic market, and that they break up the solidarity of workers, but, generally speaking, trade unions are not opposed to payment by results where a satisfactory standard of measurement can be found Group piece rates are often of high practical importance, and refer to the system of paying a fixed sum to a group of men on the completion of an assigned task

In some cases a collective bonus is the only possible alternative to pure time work, the bonus being usually allocated in proportion to the men's basic rate of pay It is advisable to limit the groups to operators whose work is related The efficiency of corporate effort depends, of course, on the skill of the management, and, moreover, if a group is made too wide it may well be that the increased production for which the bonus is being paid arises from the efforts of a relatively small portion of the group Nevertheless, the risk is sometimes taken, and in order to stimulate collective effort, a bonus may be paid to all the employees if the total output of the works exceeds a standard amount The stimulus given by payment by individual results is, however, usually more effective in increasing efficiency

Another method of payment is sliding-scale wages, an arrangement for regulating wages according to the market price of the commodity or the profitableness of the industry Another similar method is where wage levels are altered according to variations in the cost of living index This has the advantage that the wage variations are automatic instead of involving lengthy negotiations and, perhaps, strikes Selling prices are, however, an inadequate test of economic conditions as they do not allow for changes in the cost of production or in the volume of trade

The remuneration of most workers is governed by both time and piece work factors Most systems have a framework of time-rate considerations, including the various incentive wage systems involving the payment of a premium or bonus Piece wages and bonus systems must be based on time and motion study, which is considered in an earlier chapter Incentives which, though not a part of the wage system, have been devised to give the workers a financial interest in increased productivity include profit sharing and co-partnership and will be considered below It is, of course, deplorable that the majority of workmen have no interest in the industries of the country beyond the wage they receive Particularly since the rise of joint-stock companies, personal contact between employers and employed has tended to disappear The employers are, of course, the shareholders, who often have no knowledge of or contact with the industry whatever, and are mostly concerned with the dividends earned

The distribution of wages between one occupation and another depends fundamentally on competition, but the competition is not free or open, owing to differences which are inherent in some cases, to lack of educational

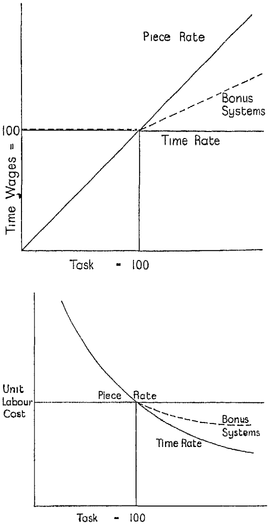

Fig 80 Variation in Wages and Labour Cost with Increased Output

opportunities in others, to conservatism, to imperfect mobility of labour, and to artificial restrictions imposed by trade unions or professional and other bodies

INCENTIVES

It seems only logical to relate wages to the amount and quality of the work performed The main difficulty lies in measuring the services of the workman All incentive systems depend on time studies and, if we suppose standard times or standard rates to have been established, then the choice lies between piece work and its variants and premiums bonus systems

If a workman saves time on the standard set, to whom does the value of it belong?

Under time work, labour gains nothing, though the labour costs and overhead costs are lowered

Under piece work, labour gains all the time saved and labour costs remain constant, though overheads are reduced

Under premium-bonus systems, the firm and the workman share the time saved, and both labour cost and overhead costs are lowered

Fig 80 shows the daily wages and the labour cost in relation to daily production under the three systems[1]

Under piece work the employer has little or no incentive to provide facilities and improve conditions except in so far as overhead costs are lowered The determination of standard times is important It is always possible to make a mistake in setting piece rates and difficult to correct it owing to the bad effect of rate cutting, but under a bonus system mistakes are less onerous and less costly With new work it is advisable to establish temporary piece rates subject to revision or cancellation

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[1] The total factory cost per unit decreases under all three systems, but above task level faster under day rates than under the piece system, with bonus systems intermediate A system of wage payment is, of course, conceivable under which the labour cost increases per unit and the total unit cost remains constant

A variant of piece-work payment is called the differential piece rate, being in fact the original Taylor system A standard rate was set for the workmen achieving the task level with a much lower figure for those not working

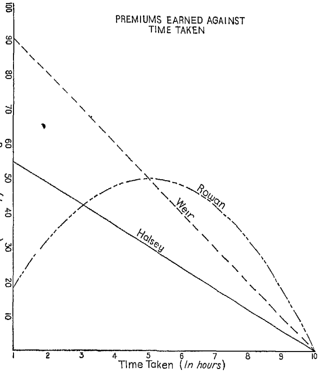

FIG 81 PREMIUMS EARNED UNDER BRITISH SYSTEMS

at this rate It was intended to penalize the slow worker, and inefficient men were removed from the shop Subsequently, an intermediate rate was introduced (85 per cent of the task) and multiple piece rates, being flexible, serve the purpose of grading employees The straight piece rate, in which the reward is in direct proportion to the effort, has, however, many advocates who consider it the simplest and soundest method

BRITISH PREMIUM METHODS

Of the various methods in which a fraction of the amount of time saved from the standard time is credited to the

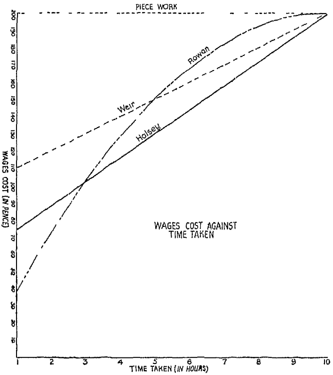

FIG 82 LABOUR COST UNDER BRITISH PREMIUM SYSTEMS

workman we may distinguish as to whether the fraction is constant or variable Under the Halsey and the Weir systems the fraction is one-third and a half respectively, and under the Rowan system it is the ratio of the time saved to the standard time

Let H_s = the hours allowed or standard time
H_A = the time taken on a job
R_h = the workman's rate per hour

Then under the Halsey System the bonus equals

$$B = \tfrac{1}{3}(H_S - H_A)R_h$$

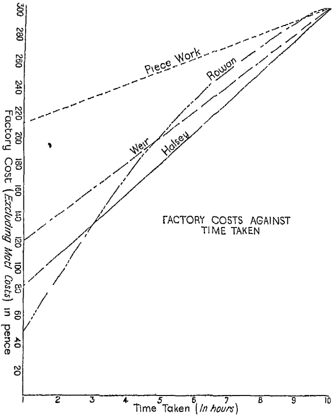

FIG 83 FACTORY COSTS UNDER BRITISH PREMIUM SYSTEMS

and the man's earnings equal

$$R_h \ H_A + \tfrac{1}{3}(H_S - H_A)R_h = \frac{R_h}{3}(H_S + 2H_A)$$

Under the Weir system, $B = \tfrac{1}{2}(H_S - H_A)R_h$

$$\text{and earnings} = \frac{R_h}{2}(H_S + H_A),$$

Under the Rowan system

$$B = \left(\frac{H_S - H_A}{H_S} \quad H_A\right) R_h$$

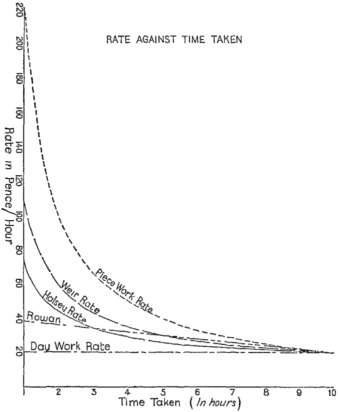

FIG 84 WORKMAN'S RATE UNDER BRITISH WAGES SYSTEMS

and earnings equal

$$R_h H_A + \left(\frac{H_S - H_A}{H_S} \quad H_A\right) R_h = \frac{R_h}{H_S} \quad H_A(2H_S - H_A)$$

The incentive from the Weir system is high if the standard times are generous For small savings in time the Rowan system gives the larger bonus, when half the time is saved the two types of bonus are equal When the time saved is greater than a half the Weir bonus is the greater

Figs 81 to 84 show a comparison of premiums, rates and costs under the three systems mentioned for a specific job rated at 10 hours for a workman at a standard rate of 1s 8d and an oncost of 10d per hour

AMERICAN BONUS SYSTEMS

The Gantt Task and Bonus Plan guaranteed an hourly rate up to the achievement of a standard task, but, if completed in the standard time, the hourly rate was increased 20 per cent When the standard task was exceeded, a percentage of the time saved was paid to the worker in addition to the higher rate The system was based on the idea that the sharp jump in rates at the task point caused a workman to accomplish the standard every time Under this scheme the foremen may be paid a bonus if a specified number of men earn a bonus

The Emerson Efficiency Plan guaranteed a day wage and, having set a rather high task level, paid the workman a bonus based on his efficiency ratio measured by the ratio of the standard time to the time taken At 66 per cent a small bonus was paid, increasing up to 20 per cent on the guaranteed rate at the task level Above the task level the man was also given the time saved The Emerson plan had the advantage of a gradual transition over day rates as efficiency increased from sub-standard to super-standard work

Special difficulties may arise in connection with beginners under incentive plans It is usually considered best to pay them an auxiliary sum at the start Some plans have been devised with consideration for beginners specially in view such as the Barth Plan, in which the hourly rate aid was the square root of the ratio of the standard time to the actual time multiplied by the standard rate

The Bedaux System

The Bedaux Point Premium Plan, formulated in 1916, is the best-known of the gain-sharing plans based on the predetermination or standardization of the amount of work to be done in a time unit of a minute For each job the amount of useful work performed by an average operator per minute, making due allowance for rest and delays (i e dependent on the nature of the effort), is called a B point or unit It is the amount of work a normal operative will do in one minute at the normal speed under ordinary conditions, and 60 B's constitute an hour's task The point standard for a job is the number of B's allowed for a given piece of work The number of B's produced by each individual is posted per day, and the value of the number in excess of 60 per hour is shared by the direct and indirect labour The worker concerned may get 75 per cent or even 90 per cent, the balance going to the indirect labour and supervisory force It will be seen that the labour cost per piece is constant as in any piece-work rate plan, but the earnings are usually lower than under a piece rate owing to the high task set With the usual nomenclature, it will be seen that the earnings of an employee are—

1 Up to the task set

$$R_h H_A$$

2 Above the task

$$R_h H_A + \tfrac{3}{4} R_h (H_S - H_A) = \frac{R_h}{4} (H_A + 3H_S)$$

Base rates are established on a job by time studies and depend on the skill, experience and responsibility involved, and the Bedaux premium is proportional to the effort exerted above the standard Delays are reported in minutes and allowances are made as follows If the department is responsible for the lost time, as in the case of machine stoppages or waiting for work or trouble with materials, the equivalent points are given to the employee and charged against the supervision bonus If the lost time is due to the employee's fault he is not, of course, credited with the B points he might have performed A checker makes out daily premium cards which are posted to a premium posting sheet showing each operator what his efficiency was on the previous day and the bonus earned An analysis sheet shows the efficiency of the direct and indirect labour together with their cost and reasons for deviation from the standard A weekly recapitulation sheet provides an overall index of general efficiency of the department on which supervision bonus is paid

It will be seen that the plan involves an incentive to direct labour based on its efficiency and an incentive to indirect labour based on the productive work done, or the ratio of standard labour costs per point to actual labour cost per point

The limitations of the Bedaux plan include the cost of time studies, checking and clerical work, the amount of inspection required, and the facts that it gives little or no thought to improvements in methods and does not control direct or indirect material costs

The plan has more to recommend it as a means of strong managerial control than as an incentive wage system

The Haynes Manit Premium Plan, first used in 1924, is another system based on the amount of work which should be performed in a minute as a unit, jobs being measured in standard man-minutes of work Standards are established by time study, and a manit is four-fifths of the full amount of work a normal average workman can do in a minute throughout the day without over-exertion The standard rate of production is 60 manits per hour and the normal rate usually about 75 manits per hour At first the task level was set rather low, and of the time saved one-half went to the employee, one-tenth to supervision, and four-tenths to the firm When the system became more standardized five-sixths was given to the workman and one-sixth to the supervision The employee's earnings (with the usual nomenclature) were therefore

$$E = (5H_{\mathrm{S}} + H_{\mathrm{A}})\, R_h/6$$

In a later plan the full saving was given to the direct producers and supervisors, and indirect labour was rewarded by $4\frac{1}{2}$ per cent on the combined earnings of direct labour, this, of course, coming from the savings in overheads from increased production

Under this system no credit in manits was allowed for bad work This plan is also a good production control system as it draws attention to production hold-ups such as waiting for work

The accompanying diagram may be useful in indicating the interrelation between time wages, piece wages and the various bonus systems It can, of course, be suitably augmented to include the other premium plans

GROUP INCENTIVES OR COLLECTIVE BONUS PLANS

The aim of incentive plans is, of course, to increase production in unit time Under individual systems the incentive is strong and immediate, but other measures are required to maintain quality and co-operation between employees In continuous processes, production and assembly lines, or where the efforts of a number of workers are required to complete a part or job and it is not practicable to obtain the output of individuals, it is necessary to pay a group bonus if it is desired to retain the incentive payment idea Wherever a process or organization is collective in character, a group bonus may be found advantageous It will be seen that the idea might be extended to a whole shop or works, but it is usually not advisable to do this The group must not be too large for the community of effort to be appreciated by each member In other words, there must be belief by the individuals in the group idea and that the remuneration for extra effort is being shared justly and reasonably

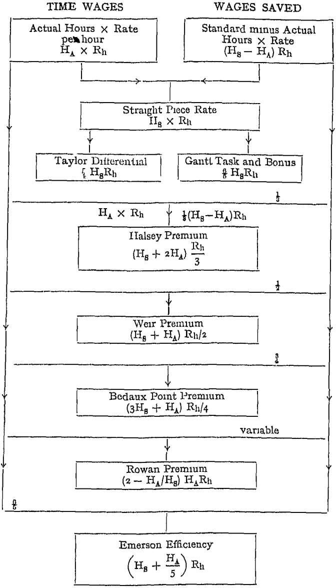

FIG 85 DIAGRAM SHOWING INTERRELATION BETWEEN TIME, PIECE, AND BONUS SYSTEMS

Whilst not so strong an incentive as when the emphasis is on individual performance, a group bonus constitutes a steady and persistent stimulus to organized effort Community of interest engenders co-operation and team work, the skilled help beginners so that the amount of training and supervision is reduced The working environment will be more pleasant, quality may improve, conscientiousness and alertness are promoted in reducing scrap and defective workmanship Time-keeping, checking and costing are simplified, and a saving in clerical work may be effected

The group basis stimulates co-operation and loyalty, but it must, of course, be backed up financially Simplicity of understanding the scheme and confidence in the management are just as requisite for satisfactory working as in the individual systems discussed above There must be no arbitrariness or suspicion Disadvantages that have been suggested against group bonuses include the fact that there is no check on individual efficiency and exceptional ability may be penalized There may also be some difficulty in arranging payment for uncompleted jobs

ESSENTIALS OF A GOOD INCENTIVE PLAN

It is considered that the requirements of a good incentive wage plan are—

1 There must be a guaranteed minimum wage

2 The plan must be just to employer and employee

3 It must have the support of the management and the employees

4 All standards should be based on time study

5 Standards must be guaranteed against change unless methods alter

6 The plan must be reasonably simple so that the employee can figure his earnings

7 There must be a proper incentive, if the standard is high the reward must be generous

8 There should be no restriction on the amount of earnings

9 The plan must assist supervision and, if possible, aid team work

10 The plan must not make costing difficult

Each firm must choose the plan best meeting its own work and circumstances There is no best made-to-order plan, and it is a good point to preserve flexibility in the system adopted In any case, great care is required in the introduction of an incentive plan The normal British operative resents what is new, scenting speeding up and driving in these matters, and it is necessary for the management to win the confidence of the workers, explaining what it is doing and the reason for and purpose of doing it

A vexed point arises in how to deal with spoiled work Various alternatives have been suggested (1) make the workman do it over again in his own time, (2) put the workman on a time rate for the period covering the spoiled work, or (3) give no credit for spoiled work, but if it is not due to the operator's fault, make a special allowance, such allowance having to be applied for first to the rate clerk or, if disputed, to the works manager

INCENTIVES ON OTHER FACTORS THAN QUANTITY

Besides greater output, greater accuracy and higher quality should be encouraged It is sometimes possible to pay a bonus on quality, for example, a graded bonus decreasing with increase in the number of rejects and ceasing altogether above a certain percentage Waste may be discouraged by paying a bonus on savings in material, i e the bonus is inverse to the waste Bonuses may also be paid on safety records, length of service, regular attendance, reduction of indirect labour or in maintenance costs

PROFIT-SHARING METHODS

Profit sharing is a method of evoking the collaboration of labour with ownership by giving the workers a pecuniary interest in the making of profits It is based on the idea that optimum output is only forthcoming when the worker can identify the success of the firm with his own personal profit Profit sharing antedates time and motion study and incentive wage payments, one of the earliest profit-sharing schemes being that of the Maison Leclaire, started in 1840 On the whole, profit sharing has had a chequered, sorry history, a large proportion of schemes having been abandoned The average life of schemes in this country has been 14 to 15 years and the average bonus 5 to 6 per cent addition to wages From the workman's point of view it is claimed that the return is too small, too far off and too uncertain to be a fitting incentive to greater productivity, and such schemes may be directed against his trade union loyalty and side-track his main interests

Whilst it is highly desirable to interest all parties in the successful running of a works, it may be asked what role does the efficiency of labour play in the making of profits? Profits are dependent on so many factors, for example the state of trade, the suitability of the plant, the manufacturing policy, wise buying, effective selling, efficiency of organization, and so on It seems, therefore, more optimistic than practical to assume that efficient effort on the part of the workers may counteract any or all of the above factors which may be inefficient or wrong Moreover, the incentive of profit sharing is generally absent just when it is most required, viz when earnings and employment are low

As it is not suggested that the workmen should share in a loss on the past year's working, the logic of the reverse is not apparent

One might go further and ask what are profits, and are they ever known, or is it desirable that they should be known outside the highest officials of a firm, in view of the agreed necessity of reserves to ensure the stability of a modern undertaking?

Most profit-sharing schemes constitute a form of employer's benevolence, the rates and conditions of receipt (usually depending on length of employment) being fixed by the firm So long as the true nature of profit sharing is recognized, it will be all to the good as an extra inducement to increased industrial efficiency and improved industrial relations Moreover, there may be engendered a corporate spirit among the workers which will frown on waste of time and material in so far as this is conceived to lessen the chances of a bonus Profit sharing is not, however, a form of payment by results, as a profit is not necessarily ensured by a high rate of production It is in no way a substitute for the incentive systems outlined above in which there is a clear-cut and definite issue, viz an extra wage payment for increased application to the factors within the workman's control

CO-PARTNERSHIP

Profit sharing may assume various forms and, whilst cash payments predominate, the bonus may be paid in shares allocated to the workers from a block reserved for this purpose It is, however, difficult to dissociate this from co-partnership The latter implies that the employees become shareholders in the business, and it is assumed that their feeling of responsibility in this capacity will cause them to have the interests and welfare of the firm at heart and facilitate co-operation, thus diminishing or avoiding trade disputes

There are several types of co-partnership schemes Some are wholly benevolent, others are directed to making it as easy and convenient as possible for the employee to become a shareholder In any case, labour is not as a rule in a position to purchase shares outright, and co-partnership is usually anteceded by the reservation of a fund to purchase the block of shares which the employees will eventually possess Under the benevolent type the shares may be allocated to workers as their length of service increases, but they may hold no voting powers and must be sold back to the firm when the employees leave In fact, restrictive conditions are nearly always imposed, even if the employee is merely assisted to buy the shares in instalments. Sometimes co-partnership committees are formed to advise the management on relevant matters and a representative of the employee co-partners may even sit on the board of the company, but control always remains with the employers.

It is generally agreed that contributory schemes are preferable and that trade unions should still be recognized and collective bargaining retained, though it is to be anticipated that a better spirit will be found in wage-bargaining operations. It is reported that about 50 per cent of co-partnership schemes have failed to continue. They are usually dropped in bad times. It has been pointed out that the employee-shareholder carries a double risk, viz. that of losing his capital and his job. Co-partnership schemes are most suitable for public-utility companies, but in ordinary industrial concerns the subject is bristling with difficulties. Most people are agreed, however, that everything should be done to encourage and facilitate investment by workers in industry. The need of employees for security has been recognized in some cases by the company limiting their holding to special bonds which are not only secure but easily redeemable. It has also been suggested that the workers as a body should form themselves into an investment society registered under the Provident Societies Act.

The workers' representatives should be helped to acquire knowledge of the working of the industry and their own firm in particular. It will assist towards confidence and co-operation. Co-partnership schemes are, however, no substitute for an enlightened wage policy.

NON-FINANCIAL INCENTIVES

In addition to the hope of higher earnings from greater output, there are a number of inducements to further effort by employees, such as competition, fear of dismissal, and probability of continuous employment. There is also the mass incentive of activity and drive. Good management is in itself an incentive Confidence in the management and belief in its sincerity and goodwill will stimulate output Interest and pride in the work and knowledge of how the individual's work fits into the general scheme may also have a beneficial effect The incentive of appreciation may be employed to stimulate loyalty and interest in the firm Other incentives include encouragement of suggestions, good physical conditions and the reputation of a safe shop Efficiency is encouraged by promotion possibilities Promotion policies should be carefully reviewed, explained and charted The adaptability of a live organization attracts a good type of worker A good costing system is an incentive in itself When workers know that costs are being carefully analysed and scrutinized they are impelled to maintain their efficiency The efficiency value of good personnel officers has already been discussed

Managerial incentives include adding to responsibility and sense of authority, increased freedom of action and opportunity to build up an organization and performance against budgeted standards

SHOULD FOREMEN BE PAID A BONUS?

There are a number of ways of paying a bonus to foremen, of which two will be mentioned a bonus on the workmen's bonus, and composite bonuses related to various constituents of the foreman's responsibility, e g percentage of rejected work and average productive efficiency of the group, the number of standard hours' work accomplished, the time lost in delays, unit labour cost, percentage of scrap, reduced shop overheads, and so on It will be seen that the establishment of these composite bonuses depends on the predetermination of good average shop practice in regard to the various factors

There is a good deal to say for and against this proposal, but the author has been rather surprised to find that several discussion groups of foremen and supervisors have passed a majority vote against it There seems, however, to be an extension of the principle of making incentive payments to foremen and, in fact, to every grade of executive

TIME-KEEPING AND WAGE PAYMENT

Accurate time-keeping is the basis of wage analysis and ascertainment of labour cost The work of the time office facilitates the correct calculation of wages by accounting fully for each workman's time, which ensures that productive labour is kept as fully employed as possible

The method of recording time requires careful attention as it is essential to know not only the period that a man is on the premises but the time actually spent at work and on what jobs

The traditional method of time-keeping comprised recording the former point only, for example, by a watchman at the gate who knew the men or had some simple tally system in use It is, of course, still necessary to record the total hours of attendance, and in some cases a double check tally system is used, viz a main tally board at the gate and departmental tally boards under the supervision of the foremen The time-keeper is able to keep a simple record (manual time-sheet) of absentees and late-comers, together with overtime hours worked From the point of view of on-and-off times, such a system may be as good as a mechanical recording system, but the latter gives more information In any case, the time-keeper will allocate employees' numbers and instruct, if necessary, in the use of the recording system

A good deal of clerical labour in issuing short-time or overtime slips and in making up time sheets is eliminated by the use of clock recording systems The total hours per week are ascertained from the time card on which wages particulars are subsequently filled out as shown in Fig 86

The location of time-recording clocks requires consideration, especially in large works Where distances are great, it may be preferable to have one at the entrance to each department rather than produce congestion at the main gate

Routine at the clocks is too well known to need description Both dial time recorders and card recorders are in use, but the latter are preferable The responsibility for time-keeping—lateness, absenteeism, overtime working, etc —

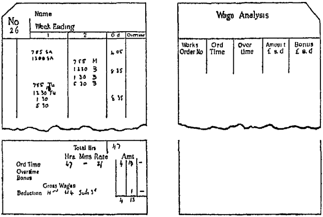

FIG 86 TIME CARD

vests in the works manager, though he may delegate it, and the employment officer may occupy himself with this work A chart of lost time and the cost of lost time should be kept

JOB-TIMING

Where the operative is not engaged on work of a continuous nature, lost time may easily arise and job-cards should be used, which are time-stamped by a clock recorder in the shops The job-time total must be "agreed" with the worker's in-and-out times, any disagreement representing idle time from machine breakdown or other cause

Manual time sheets are still used with columns for Order No and Beginning and Finishing Times, which the employees fill in and the foreman countersigns, the columns for total hours and money values being filled out in the time office Automatic time records are, however, always preferable, though special cases may arise, e g in the case of gangs or of service work Care should be taken to see that there is only one card per man per job and that the job clerk has the next job in order with the card ready

When a job-card is clocked off, the time is abstracted, converted into wages and bonus, if any, and the data transferred to the job cost and the workman's wages compilation

PAY-ROLL COMPILATION

Efficiency in the preparation of pay rolls depends on the soundness of the time bookings Simplicity is the desideratum of any system

In time books the daily entries are totalled for the preparation of wages sheets Suggested headings for the latter are Clock No , Name, Rate, Hours, Wages, Overtime, Bonus, Total Wages Deductions, Net Wages Copies will be sent to the cashier and the cost office

As much use as possible should be made of labour-saving machinery, but for comparatively straightforward wage extensions a ready reckoner is usually regarded as superior to the calculating machine

There are many pay-roll machines in use, for details of which specialist books should be consulted as well as for particulars of pay-roll compilations by means of the Burroughs machine or the Hollerith or Powers-Samas equipment A Burroughs machine will give the pay roll, a record of earnings, a pay envelope and a receipt in one operation In punched-card systems not only are the clock cards used as original documents but as permanent records of "punched" information In addition to preparation of a summary, any desired analysis of the information may be made by simply running the cards through the tabulating or sorting machines These machine methods are also useful for the preparation of statistics and records, such as National Insurance data, income-tax returns, trade association returns, and so on Another advantage lies in the fact that as output, direct and indirect wages, etc , can be quickly ascertained many "management ratios" are readily available for the use of the works manager, employment officer or other officials.

PAYMENT OF WAGES

From the firm's point of view the payment of wages is an unproductive expense and must be reduced to a minimum cost Many firms find automatic cashiers of much utility in making up wages, and other time-saving devices are available for folding notes and sealing envelopes, the sealed-envelope method of paying wages being the one most used Time economy in the stamping of insurance cards results from the use of a mechanical affixer

IMPORTANCE OF INTERNAL CHECKS

In all pay-roll systems checks are necessary to prevent or to locate possibilities of fraud and error These checks may not mean duplication of effort, but a good safeguard against collusion is the subdivision of duties so that the results of the work of one man or a department will prove a check on another Check control is necessary in the following time booking, extension of time wages, calculation of piece-work amounts, posting piece-work amounts to the pay roll, totalling of gross wages, cash analysis and make-up and actual wage payment

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CHAPTER X

CONTROL OF EXPENDITURE

EXERCISE of control over expenditure in a manufacturing business is the main function of the cost accountant Cost accounting is an integral part of all good management The ascertainment of costs is not an end in itself, but the object is to provide means whereby costs can be controlled It is necessary for a works manager to be an expert in the mechanical processes his work involves, and possess the ability to direct and control men, but these abilities do not complete the requisites for the successful performance of his function We have already noted in Book I (Chapter XIV) that he must also possess a cost sense, or ability to analyse the cost of operations, materials and expenses under his control with a view to carrying out manufacture at the minimum cost This does not mean that an engineer must acquire an expert knowledge of accountancy Accountants extract and present figures which form the background of economic production, covering a wider ground than the origin and incidence of manufacturing costs The works manager must, however, consider it part of his job not only to control the direct costs of production but to understand, scrutinize, and be responsible for shop expenses and their incidence He is engaged to produce at or below a predetermined cost, or in the absence of a budgeted cost at the minimum practicable cost To this end he must know not only how efficiently labour and materials are used, but also the non-productive services which he has to employ in running the works A costing system must be adapted to suit the nature of the works it deals with, and this can only be achieved by the fullest collaboration between the works manager and the accounting department The former must understand that the accountant's passion for detail is not fussiness, but arises from his knowledge that, unless cost accounts are accurate, they are of no use at all, and that collaboration will greatly assist the engineer's task of economic production On the other hand, the expense of a costing system must be covered by the results Moreover, the system must be properly used A rough system may appear to give good results, but may not be capable of being properly checked

IMPORTANCE OF COST ACCOUNTING

Costing is a management mechanism which portrays in money values the activities of the firm Scientific costing cannot be achieved with haphazard factory methods, and it is significant to observe that, when reorganization of a firm proves necessary, one of the first steps is to appoint a cost accountant in control The co-operation of the accountant should be welcomed by the works executive as his aim is to increase efficiency by indicating waste and leakage of materials and time and uneconomic factory expenses

In the past, accounting was limited to the statement of money transactions and stock-taking, the results being set forth in the Trading and Profit and Loss Accounts, but leakages of material and wasted labour were not revealed Competition, however, rendered imperative the ascertainment of costs as the starting point of investigation of their possible reduction The significance and importance of cost accounting were, however, only slowly recognized, after the war one government department was forced to state that only 5 per cent of British manufacturers knew their costs Since then the science of cost accounting has developed rapidly and reached a high degree of refinement in what is admittedly difficult work Even to-day accountants would hesitate to claim to say what the exact cost of an article is where overheads are concerned

Cost accounting is, however, a vital factor in scientific management Although the costing department is itself an overhead expense, and like every other expense must justify itself by yielding a revenue, so important is its work in improving productive efficiency and enabling a complete control of expenses to be exercised that it is inconceivable for a firm to exist without a costing system

COSTS OF PRODUCTION

It has been observed that the requisites of production are land, capital, labour, and management, which are employed in various relative amounts in different industries The remuneration of these four factors constitutes the cost of production We may note that one measure of the importance of an industry is the increase in value given to the raw materials in the manufacture of the finished products For the same value of finished goods some industries create more than nine times as much wealth as others Highly developed machine and chemical industries show low labour charges but high investments As operations become of greater duration and complexity, greater capital is required The greater the quantity of machinery the lower the labour charges per unit of production, but the costs have to include charges for maintenance, depreciation, and possibility of obsolescence The productivity of labour increases with the amount of machinery put at its disposal, this may be illustrated by the fact that its efficiency in producing wool has increased four times during the time that its efficiency in turning wool into cloth has increased over fifty times

The constituents of production costs are costs of materials and labour, and costs of capital, power, selling, supervision, etc , the latter costs are generally grouped under the heading of establishment charges, and are those which usually constitute the chief concern of the management The greater the production, the less the establishment charges per unit, and the less the unit cost of manufacturing

Fixed overheads continue if the plant is not running, and production must be above a certain percentage of

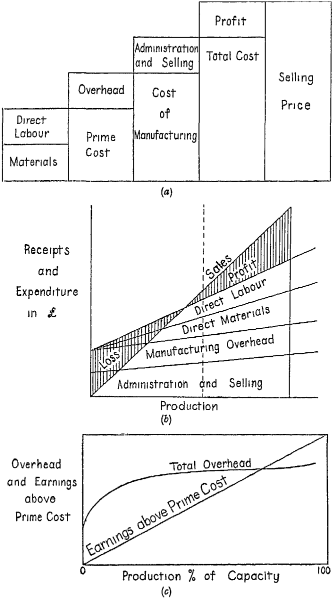


Fig 87 Relation of Overheads to Selling Price

capacity before they can all be distributed and a profit earned This is illustrated in Fig 87 (*b*) It will be seen that selling goods at a lower price may, if it results in an increase in production, save rather than lose money

In times of depression difficult problems may arise in balancing the losses due to plant lying idle against the acceptance of profitless orders, or selling some lines at a loss in order to carry a portion of the fixed overheads

It is frequently stated that costs of production in this country are high, due to high wages, this does not mean that wages are high in themselves, but high in proportion to output With increasing mechanization of industry the labour cost factor in production diminishes, but the materials and fuel factor tends to increase Hence the importance of economic design and use of material and the adoption of the most efficient methods of production

In attaining minimum production costs, however, the question of overheads is the most important, so that, in addition to the necessity for the best engineering practice, the management of an engineering works must have a full knowledge of the economic considerations under discussion, including the most economic size of enterprise, the relative costs at various scales of output, the economics of batch size, and so on

ELEMENTS OF COST

The cost elements to be recovered in the selling price, are—

Direct Materials Expenditure	Prime Cost	Factory Cost	Total Cost	Selling Price
Direct Labour Expenditure				
Factory Expense Charges				
Selling Charges				
Administrative Charges				
Profit				

or, simply illustrated in a diagrammatic form, the constituents of the selling price are as follows—

Materials	Labour	Factory Overhead	Firm's Overhead	Profit

Factory expenses include all charges applicable to production other than direct materials and labour An indication of the content of factory expenses and their subdivision may be given roughly as follows—

Indirect Materials	Indirect Labour in	Miscellaneous Expenses	
		Standing Charges	General Charges
Shop Supplies Tools, Patterns Coal and Coke Gas	Supervision Inspection Stores Tool Room Clerks Transport Time Office Drawing Office	Rent Rates Depreciation Insurance	Management Planning Department Employer's Liability Welfare Department Repairs and Renewals Power Lighting Cost Keeping Stationery Patents

Selling expenses include all costs incurred in selling the products, e g selling organization, including upkeep of sales department, wages and commissions, travelling expenses, packing, delivery, publicity and propaganda, exhibition charges, etc (See Chapter IV)

Administrative expenses comprise the cost of running the financial side of the business, directors' remuneration, and so on

These general overheads, as they are called, will not be considered in further detail here, but we may pause to note that the effect of high efficiency on the part of the works manager in achieving low factory costs may be stultified in the absence of equally efficient control of the expense of the functions of the firm other than production

The determination of selling costs is, however, as important as that of production costs to maintain an efficient business unit Admittedly, distribution of selling expense over the various goods is difficult, and usually the cost of selling is taken as a percentage of the production cost, but this is unjust A compromise may be made by classifying the products in groups in endeavouring to establish selling costs as the expenses may be more readily classified according to lines of work

ALLOCATION OF DIRECT COSTS

We have seen that direct materials appear in the finished product less the wastage caused by machining away, scrap, etc Their cost control depends on efficient stores accounting No stores should be issued into the shops without a duly authorized written order as previously indicated, this authorization may be a complete specification of materials from the drawing office, which is sent on to the cost office for charging to the particular job or order, or it may be a requisition from the shops, properly certified, and indicating the job, so that the materials may be transferred to the job cost sheet Materials found to be in excess of requirements should be returned to the stores and a credit note issued and passed to the costing department An abstract of materials cost should be sent weekly or at shorter intervals to the works manager to keep him advised of expenditure and to enable him to check progress against estimates

Cost control of direct labour involves the expression or conversion of all labour charges in terms of time We have referred to time studies in a previous chapter Knowing how long a job should take is the basis of control of the labour cost of a job The various systems of wage payment by results are directed to keeping the direct labour cost within an allowed figure If this figure is exceeded, the sources of loss on the labour cost must be carefully investigated and the inefficiency eliminated or incorrect estimating revealed The methods of time recording and time checking by means of job cards and time clocks have been referred to above The time spent on every operation in a job is converted into money value by the wages clerk and transferred to the job cost sheet

All work on a product is abstracted and booked to one order number In large companies a tabulating machine may be indispensable for such purposes The ascertainment of direct labour cost depends, therefore, on efficient time accounting and may be considered a relatively simple matter if modern methods are employed It is not possible, of course, to obtain all labour charges expressed against time, but, whenever it is economically possible to charge direct, it is advisable to do so

OVERHEADS OR ONCOSTS

The more difficult problems in the control of manufacturing operations in terms of money arise with regard to oncosts or overheads What contribution shall each product, job or class of product make to the overheads? Incorrect distribution may make a product appear remunerative when in reality the reverse is the case

From our present point of view we are more concerned with overhead costs as a factor of business economics than as a problem in accountancy Management not only wants to know what the overhead costs are and how they should be allocated, but also to understand how they behave when the production varies, so as to run the plant at the most economic load level

As no two works are alike in arrangement, organization, etc , the factors determining the choice of the particular method to be adopted must be subjected to close scrutiny and study The prime object of the method adopted is to ensure that the total expense is fully absorbed and the incidence of expenses is correct

It should be noted that increasing overhead cost is not necessarily a mark of inefficiency In highly mechanized mass production, productive labour costs are usually low and oncosts high, and as production costs decline selling costs may rise

ALLOCATION OF OVERHEAD EXPENSES

The methods of allocation of oncosts or absorption of collective charges in common use may be divided as follows—

(1) BY PERCENTAGE

(*a*) *By a percentage added to the combined total costs of direct material and labour* (*prime cost*) It must be remembered, however, that the value of the material or the pay of the workmen may have little relation to the indirect expense from job to job

(*b*) *By a percentage of direct productive labour* The percentage is the ratio of the total charges to the total labour cost of the department taken over a reasonable period This method is reasonably accurate in the absence of special conditions and has the advantage of simplicity It distinguishes between machines, but is strictly accurate only when the machines and work produced are uniform

(*c*) *By a differential percentage added to material and labour* Objections to the use of a percentage on material include the possibility of fluctuations in price of materials and the differences which exist in price and weight between the various classes of materials In some classes of engineering work, however, the addition of a percentage (e g 120) on the direct labour for general expenses and a smaller percentage (e g 30) on materials to cover the cost of handling and storage has been found to be a reasonably accurate distribution of overheads and is preferred to some of the more scientific methods referred to below

(2) BY HOURLY RATE

(*a*) *Man-hour rate* The total charges are divided by the total productive man-hours of the department and allocated pro rata to the number of man-hours on each job

The method takes no account of the use of different types of equipment, though it covers variations in the rates of pay It shows up the effect of employing cheaper labour over a long time The method is not accurate if diversified products are made, but finds an application in fitting and erecting shops

(*b*) *By machine-hour rate* The total charges are apportioned to the individual machine tools and divided by the number of hours each machine tool operates It takes into account variations in size and type of equipment, power required, size and type of product In some cases it may not be practicable to carry the division of expenses down to individual machines, and an hourly rate for a group of machines may be utilized In spreading the total oncost of the department over the machines, the whole of the expense necessary to keep the shop in operation must be caught up and distributed in accordance with the burden created by each machine

Later in this chapter we refer to a Machinery and Plant Register for recording depreciation and maintenance charges This register may also be used for recording the share of each machine of the other oncosts of the shop, for example, under the following headings—

Building or Housing Expenses—rent, rates, taxes, insurance, heating, lighting
Power Expenses—metered separately if possible
Supervision
Indirect Labour
Supplies
Miscellaneous

Some of the charges are individually known or can be measured (e g power), others have to be estimated on some rational basis (e g the amount of floor space occupied by the machine)

The total divided by the production hours is applied for every hour the machine spends on a given job, that is, added on to the direct labour and material cost

Typical oncost hourly rates used in machine shops for estimating purposes are as follows—

Per hour s	d	
1	6	Assembling and light fitting
2	0	Erecting, sensitive drilling and small machines
2	6	Small lathes, column and light radial drilling, small milling machines
3	0	Polishing machines
4	0	Small power presses, large lathes, small autos
5	0	Medium power presses
7	6	Large power press, boring machines, lathes, and milling machines, drop stamps
15	0	Special precision machines, heavy double action presses

A cost lay-out based on machine-hour overhead is shown on page 345

Where the proportion of direct labour cost is small compared with that of materials or operating the machines the labour cost may be included in the overhead, e g in the case of a man operating a number of automatics, the labour cost is almost constant per unit of production and is included in the machine rate, which is added to the materials cost

It will be noted that an increase in the volume of work will decrease the actual machine-hour rate and a fall in volume will increase the rate, and we are faced with over-recovery and under-recovery respectively The subject of idleness oncost will be referred to below

(c) *A combination of* (a) *and* (b) The man-hour method brings out the effect of employing differently rated labour and the machine-hour method the effect of using differently rated machines, and it might be thought that a combination might possess the advantages of both, but this is rarely practicable It is better to sectionalize and use the method best adapted to the work of each section, adding, if necessary, a general hourly rate to catch up expenses which cannot be allocated to any section but are shared by all

(3) BY UNIT RATE

Tonnage or other unit of production The total charges

Part No
Form Mild Steel Stamping
Weight

Date
Price

Op No	Operation	Machine	Time Mins	Labour Rate	Labour Cost (add 25% for P W)	Machine-Hour Rate	Oncost	Labour Plus Oncost
1	Turn large end	Capstan	10	1s	2 5d	4s	8d	10 5
2	Turn small end	Capstan				4s		
3	Turn neck	Centre lathe				3s		
4	Mill flange	Horizontal miller				3s		
5	Grind flange	External grinder				4s		
6	Drill	Sensitive drill				2s		
7								
TOTAL								

FIG 88 COST LAY-OUT WITH MACHINE-HOUR OVERHEAD

are divided by the total output This method is applicable only to shops which manufacture one type or class of product

As oncost loading is fixed in advance of a given operating period, charges and production have to be forecast, and the use of the words total charges, total output and total productive hours refers to either forecasted figures or normal rates Such figures are established by study and experience Normal rates can only be determined from a period covering seasonal or cyclical fluctuations, and then there will be a difference in each period from the actual expense This difference will have to be absorbed in the Trading or Profit and Loss Account On the other hand, rates fixed for short periods which will exactly absorb oncost expenses are likely to result in widely fluctuating oncosts which are not true, normal oncosts

IDLENESS ONCOST

The causes of idle machine time may be mechanical defects, shortage of labour, or administrative shortcomings, They may be analysed as follows—

Mechanical failure of power, plant breakdown, tool breakdown

Labour shortage, accidents, sickness, strikes, unsuitability

Supervisory supplies shortage, work shortage, bad planning

During idle hours overhead expenses are mounting up and, except for a few items, the oncost is the same, whether a machine is working or not Although part of the plant is standing, the factory may be working with high technical efficiency In this case, is the works to carry the burden of idle time and say that the cost of production has gone up? It is suggested that individual products should only be charged with the share of the overheads they actually use The cost system must record the full expenses incurred during the period, but the idle overhead must be brought out separately and debited to the Profit and Loss Account

Overheads are not a fixed charge per unit, but vary with the volume of production They may be divided into two constituents, one fixed and the other variable in relation to volume In the fixed portion of overheads, profit or loss will arise according to whether the actual volume of production exceeds the budgeted output or falls below it

Example—

Assume a production department having overhead charges per week as follows—

Constant overhead charge	£100
Variable overhead charge	£64 for 80% capacity working
Overhead cost per product	4 92d

and that costs have been based on this corresponding to a production of 8000 products per week

Suppose now

(1) The department drops to a 50 per cent load—

Constant overhead charge	£100
Variable overhead charge	£40
Overhead per unit (5000 products)	6 72d
Loss on overhead per unit	1 8d

(2) The departmental load increases to 100 per cent—

Constant overhead charge	£100
Variable overhead charge	£80
Overhead per unit (10,000 products)	4 32d
Gain in overhead per unit	0 6d

As overheads are forecast for each trading period, if the volume of production is larger than anticipated they will be over-recovered in a period of prosperity, and the point arises whether this over-recovery should be considered a part of profits It is suggested that it should rather be carried to a reserve to meet under-recovery in times of low production This assumes, of course, that prices are stable

DEPARTMENTALIZATION

For the proper distribution of overhead expenses departmentalization is necessary according to the manufacturing

	INDIRECT MATERIAL						INDIRECT LABOUR		Total Departmental Cost
	S D Material	Coal and Coke	Electricity	Gas	Stationery	Miscellaneous	Supervision	Labour	
Production Depts A B C D									
Total P.D									
Service Depts A B C D									
Total S.D									
Total P.D and S D									
General Charges Standing Charges Factory Oncost									

FIG 89 DISTRIBUTION OF INDIRECT PRIME COSTS TO DEPARTMENTS

		ALLOCATED COSTS OF SERVICE DEPARTMENTS AND GENERAL OVERHEADS									
Production Dept	Cost of Department's Indirect Material and Labour	Drawing Office	Inspection	Stores	Tool Room	Time Office	Packing and Transport	Electricians and Millwrights	General Charges	Standing Charges	Total
A											
B											
C											
D											
Total											

FIG 90 DISTRIBUTION OF OVERHEADS TO PRODUCTION DEPARTMENTS

operations The amount of indirect cost incurred by the various departments varies to a large extent Charges for inter-departmental services may present considerable difficulty if left till the end of the year, and they should be entered promptly The actual cost of running each department will be accurately obtained and will have a good psychological effect The control statement may start with the allocation of indirect materials and indirect labour to the departments, including production and service (see Fig 89)

The cost of the service departments may then be distributed to the production departments as suggested in Fig 90

The value of this detailed analysis showing the absorption of overheads by each productive department as a means of control will be apparent

In controlling overheads management is concerned with relating responsibility to individuals, and if overheads are divided into a series of services each in the charge of one person, his performance or efficiency may be measured by comparing actual with potential results

Overheads can only be controlled by budgeting in advance in detail by departments and fixing definite allowances for the officials in charge The efficiency of each shop can naturally only be judged from the course of the proportion of costs under its own control

Dr *Cr*

	Material	Labour	Overhead	Total		Material	Labour	Overhead	Total
Stock, 1st August	—	—	—	—	Cost Value of Output	—	—	—	—
Material	—								
Wages Productive		—							
Non prod			—						
Rent and Rates									
Power									
Insurance									
Depreciation									
Heat and Light									
Maintenance					Stock, 31st August	—	—	—	—
Salaries, etc					Balance (Loss)	—	—	—	—

Some firms in assessing the profitableness of departments draw up a manufacturing account for each by crediting the department with the cost value of the output (from estimate, or allowed proportion of the selling price) Such an account is shown on page 350

The firms may keep a running summary of each department's work, which will not only show the trend but no doubt suggest points for investigation

Month	Material	Labour	Overhead	Total	Profit or Loss	Progress and Profit

The control of overheads is facilitated by dividing into classes for example on the following lines—

1 Fixed standing charges (rent)

2 Normally constant charges (salaries, estimating and cost departments)

3 Slightly variable charges (heating, lighting, fire insurance)

4 Dependent on factory turnover (maintenance, inspection)

5 Associated with a specific turnover (power)

6 Not associated with any factor (repair, buildings)

This will not only assist the management to pick out the items requiring attention but give them an indication of the line to pursue

STANDARD COSTS

Considering the historical development of costing methods, we have seen that the old system of financial accounts showed the profit or loss as a whole but did not indicate where it arose Cost accounting showed which individual lines were responsible and therefore enabled the management to decide which to develop or which to discontinue, in which lines price-cutting would be practicable if necessary to obtain extra business, and where such a policy would be suicidal Traditional costing methods, however, gave no measure of factory efficiency, and accounts were usually presented too late for the management to do anything about the facts portrayed Judgment is impossible in the absence of a standard, and the system of standard costs has been developed to meet the above deficiencies Standard costs may be defined as predetermined or budgeted estimates of cost based on normal output In other words, before work is commenced, the accountant establishes what it should cost, thus making him vitally interested in planning, and the efforts of the management are subsequently directed to maintaining the actual cost at this level or, more accurately, seeing that it does not exceed the standard and, if possible, is less This permits the detection of departures and variations as they arise, whether, for example, they represent losses through uneconomic use of material, labour or services or accidental increases due to unanticipated causes These variations are either within the control of the management or they are not, that is, they can be prevented or they cannot, but, in any case, it is necessary to know where and how they arise The aim of standard costing is to build up a detailed statement of what a product should cost and to ascertain the causes of any excess over that cost

The expenses of any department or function may be divided into those which the person in charge can control completely, those which he can control in volume but not in cost, and those which he cannot control at all

Examples of controllable variations include defective workmanship and waste of all kinds, on the other hand, idle production time, price fluctuations in materials and variations in labour rates may be considered beyond the control of the works management

Standard costs involve the principle of management by exceptions and provide a measure of factory efficiency which facilitates control of the various departments and functions Instead of presenting a whole mass of data which the management does not want to bother with, the method of standard costs sets forth only the vital figures, indicating where the planned costs have been departed from, and discloses information in a way which invites action

It is obvious that the use of standard costs is best adapted to continuous or repetition production and more difficult of application to general engineering work Nevertheless, the principle should be carried as far as practical conditions permit, and the use of budgeted costs has been successfully exploited in such non-continuous work as locomotive repairs, in which actual charges for materials, labour, and overheads are controlled in relation to budgeted figures

The general principles of budgetary control were dealt with in Book I (Chapter VII), and it was seen how a budget of a whole business is prepared, including a sales budget, production budget, and financial budget Production is regulated by anticipated demand and finance adjusted to the cost of production Production is carried out in relation to definite standards of performance set up for each functional activity, after making allowances for varying conditions, and such standards permit it to be established whether a loss or profit is to be attributed to purchasing, manufacturing, or other cause

The setting up of standards of performance or cost may require much preliminary investigation and research, as standards of performance require standard conditions

With regard to manufacturing, standards must be compiled with regard to the cost of labour and materials and also expenses Labour-cost standards involve consideration of both times and rates Under piece rates the efficiency of labour varies according to the ratio of standard hours to actual hours Under time rates variations in labour cost may be due to either changes in rates or changes in factory efficiency Variations in materials cost depend on changes in either price or quantity used for a given job

As noted above, expenses are either fixed or variable, fixed expenses including rent, rates, depreciation, etc, whilst indirect labour and materials, repairs, etc, constitute fluctuating expenses A standard may be established in relation to the number of hours required for normal output This classification of expenses segregates the cost of idleness and the cost of production, the former being carried to a Non-productive Expense Account and thence to the Profit and Loss Account, as stated above, as it is not a factor in the efficiency of the manufacturing side

Accounting by standard costs should appeal to production executives because, in preparing a statement of what a product should cost, due weight must be given to each contributory factor and attention is called to abnormal manufacturing operations In the past, cost accountants have been apt to overlook the importance of actual production, whereas under standard costs they cannot do so The accounts are drawn up to follow lines of managerial organization, and reports following rapidly on the events permit the location of, and fixation of responsibility for, excesses Reliable figures stimulate rather than hamper departmental management They also disclose tendencies in costs and enable the management suitably to modify its policy

Standard costs keep bringing back the attention of the management to profit-making in that they disclose all factors tending to reduce the budgeted profit

No engineer is, however, likely to overlook the necessity for the periodic review of standards in the light of technical developments and improved methods

COSTING STATISTICS

The culminating point of a costing system is the statistical reports made by it We have referred in a general way to the importance of statistics and graphs as an instrument of control in Book I, and costs are only a special but very important case The fundamental point to remember is that the costing system is the servant of the management and, whatever may be the key factors in the costs of a given firm or enterprise, they must be presented in a suitable form so that their significance can be immediately grasped

The cost features which may be required are too numerous to detail, but some of the more obvious ones are—

Statement of direct costs

Statement of indirect expenses, the rate charged and the true rate

Statement of factory costs and fluctuations therein

Deviation between estimated and actual costs

Profit or loss on actual orders

Ratio of factory cost to value of orders

Statement of idle time or percentage of capacity being worked, and its effect on cost

The management wishes to ensure that production is being achieved by the quickest and most economical means consistent with the maintenance of quality and fair remuneration to labour, and, therefore, it not only wants to know what the costs have been but what they should have been and the reasons for any divergencies or discrepancies To ensure that only the minimum amount of capital necessary to the enterprise is locked up, statements must be returned of the value of raw stock and work in progress, also the amount spent on new tools and fixtures

The cost summaries submitted to the management must show which lines are paying, which shops are paying, and why The information submitted must be important, that is to say, the management does not want "loading" with a bulk of detail, but only to have available the vital figures in its work of control The simpler the returns the better are they able to expose any inefficiencies or abnormalities which may arise It goes without saying that cost statements must be accurate or their whole purpose is vitiated and the management misled

The cost accountant endeavours to supply management with reliable ratios or units of measurement of the efficiency of each function To this end it is deemed more reliable to compare results after making allowances for varying conditions rather than by comparing with previous periods As regards the works side, if the cost of idle plant is abstracted, a department should manufacture with the same efficiency regardless of capacity, and after such deductions have been made from the unit costs the works manager is responsible for explaining divergencies from the predetermined standard

The cost accountant must co-operate in every possible way with the technical executives of the firm Not only can he give them guidance as regards the desirability of increasing or reducing output and desired rearrangements of personnel or methods, but he may be able to bring to their attention data on the manufacture of an article more cheaply by an alternative method or the execution of a process by another firm at a lower rate Comparative data which he will accumulate in the course of his experience in connection with either production or transport costs may be a source of inspiration to the technical managers of the concern

We have noted that, in the past, cost figures usually were presented too late for the management to take prompt action In these days of severe competition and rapidly changing conditions, the period of presentation of reports needs to be minimized In some industries weekly and even daily figures are practicable and prove of the utmost value in the determination of managerial decisions

It is of the utmost importance to bring to the notice of all executives the costs with which they are concerned, i e which their actions or decisions control Suitable statements should be submitted right down the line of control to the foremen, so that they realize how much of the expenses with which they are concerned is going in different directions

Reference may be made to the practice of some firms of submitting weekly cost data to the foremen, followed by a meeting with the works manager and accountant at which the figures are discussed and explanations called for The moral effect is marked

LINKING UP COST AND FINANCIAL SYSTEMS

In cost accounting there is, as we have seen, a certain amount of estimating, particularly with regard to oncosts The Trading Account deals with actual expenditure, yet there should be agreement between the financial and the cost accounting figures For obvious reasons, this is usually not the case, cost accounts frequently giving more favourable results Some slight adjustment is therefore necessary at the end of each period in order to reconcile the two sets of figures

We have noticed above some of the advantages of classification of accounts This procedure should be adopted as regards the control accounts in the Cost Ledger, and, if the financial accounts are subdivided and arranged in parallel with the costing system, the work of reconciliation is facilitated It should be noted that agreement between the two sets of books at any moment does not necessarily prove that the cost accounts are accurate, because the oncosts were established on the last period, whereas the expenses for the current period are not yet fully known

DIFFERENTIAL COSTS

It should be observed that the lowest price at which orders can be accepted is not, as is sometimes supposed, the prime cost, but the difference between the cost of producing and the cost of not producing, or the cost of *added* production This is called the differential cost, and is frequently a matter of considerable complexity, as it may include a number of fluctuating oncosts varying with output

Management may, however, require to know, above all else, what is the lowest price at which a given output can be sold without loss

Suppose it took £50,000 to manufacture 10,000 sewing machines and £60,000 to make 12,500, then the cost per machine is £5 in the first case and £4 16s in the second case, but the differential cost of producing the extra 2500 machines is £4 each These might be sold abroad on a basis of £4 without affecting the home market on a basis of £5 cost each This is, in fact, the principle of dumping, with regard to which some very loose statements are occasionally encountered

When it is said that the exporters of dumped goods are selling below cost, the expression is practically valueless as no reference is made to the load-factor of the factories concerned The managements of such factories endeavour to run the plants at the point of least cost per unit, and therefore the cost of producing the last "increment" is extremely low Even if they are selling below cost, their loss may be less than if they did not make the dumped goods

When the home market of the exporter is protected so that he can sell a certain number at a given price, the cost of making an excess quantity is considerably lower and he can sell them abroad at a much lower price

The principle of differential costs will also be familiar in regard to the charges for travelling by excursion train, for consuming electric power at night, and the rates for evening telephone and telegraph service as well as for deferred cables

Reverting to factory work, the management will need to know the costs for different load factors and, as in estimating oncosts, a particular loading will have been formulated, the management will be able to decide whether it will pay better to take or not to take a particular order or line of work at the price obtainable Moreover, costs will generally be lowest with uniform loading, although the sales may be fluctuating or seasonal

DEPRECIATION

The current value of a plant is obviously not the amount originally expended on it It will have diminished in value owing to the lapse of time, the influence of the elements, wear and tear in use, and perhaps it has not been maintained in effective repair New designs and inventions may have rendered available machines which will perform the work more efficiently Changes of taste or fashion or a rise in the cost of materials may have destroyed demand for the machine's products

This diminution in value of a plant or machine with time may therefore be divided into two factors, depreciation and obsolescence The latter is due to the machine growing out of date or becoming old-fashioned Depreciation is the unavoidable deterioration in value due to wear and tear in use even if the machine is kept in proper repair Maintenance or keeping in repair is in fact an additional expense which has to be provided for in the cost of running the machine

Plant and machinery are bought for the purpose of earning an income and diminish in value during their life until they have to be replaced Provision for replacement of these assets must therefore be made, and this can only be made from an equitable accounting point of view from the income derived from their use There can, in fact, be no true profits without providing for all expenses involved in carrying on production on a permanent basis

The original cost of each fixed asset, together with all expenditure thereon but minus its residual or scrap value, is therefore a charge against revenue and this charge must be spread over the asset's life as fairly as possible Its life is, of course, the period over which it is economic to retain it in service, this may be much less than the period over which it would continue to be usable

To provide the purchase price for replacement of an asset a sum of money must be deducted annually from revenue and set aside to give the desired amount at the end of the working life of the asset It is imperative to create a depreciation reserve or sinking fund, and to earmark it for the purpose To use the depreciation fund for working capital is dangerous, particularly in small businesses New capital to replace assets should never be necessary except as the result of accidental destruction or in the event of progress in invention suddenly rendering the assets valueless

METHODS OF PROVIDING FOR DEPRECIATION

There are several methods of providing for depreciation, the object being to determine the proper sum to charge against revenue to cover the deterioration of the machine or other asset The choice of method depends on the actual circumstances

1 *The fixed instalment method* involves writing off each year an equal proportion of the cost of the asset to reduce it to its residual value at the end of its life

Let I be the initial cost, R the remanent value and N the years of life

Then the sum to be set aside each year is $\frac{I - R}{N}$ This simple method makes no allowance for the fact that repairs and renewals are largest towards the end of an asset's life, and the total annual cost of upkeep will therefore be larger

2 *The diminishing balance method* consists in deducting depreciation at a fixed rate per cent on the balance outstanding at the beginning of the year With the above symbols, and denoting by p the constant percentage (expressed as a fraction) required to write off the asset in N years, we have—

At the end of the first year the depreciation fund is

$$Ip$$

At the end of the second year the depreciation fund is

$$Ip + (I - Ip)p$$

At the end of the Nth year the depreciation fund is

$$I\{1-(1-p)^N\},$$

which equals

$$I-R$$

or

$$p=1-\sqrt[N]{\frac{R}{I}}$$

This does not allow for the interest accruing on contributions

If we allow r to be the rate per cent payable per £1 on the yearly sums invested, the formula is as follows—

At the end of the first year the depreciation fund is

$$Ip$$

At the end of the second year the depreciation fund is

$$Ip\,(1+r)+p\,(I-Ip)$$

$$=\frac{Ip}{p+r}\{(1+r)^2-(1-p)^2\}$$

At the end of the Nth year the depreciation fund is

$$\frac{Ip}{p+r}\{(1+r)^N-(1-p)^N\}$$

which equals

$$I-R$$

and from which the constant percentage p can be obtained

3 *The interest law method* provides for depreciation by crediting the asset account with equal yearly amounts and debiting it with the interest that would otherwise be earned by the capital invested in the asset The interest is eventually carried to the credit of the Profit and Loss Account The annual increments, minus the interest on the yearly balances of the asset account, indicate the necessary amounts to be set aside for replacing the asset at the end of its forecasted life

Let S be the sum set aside each year

Then at the end of the first year the reserve is

$$S$$

Then at the end of the second year the reserve is

$$S(1 + r) + S = \frac{S}{r}\{(1 + r)^2 - 1\}$$

Then at the end of the Nth year the reserve is

$$\frac{S}{r}\{(1 + r)^N - 1\}$$

which equals $I - R$

Therefore, $$S = \frac{r(I - R)}{(1 + r)^N - 1}$$

This method is generally used in connection with leases and similar assets, since, when employed for machinery, fresh calculations are necessary each time additions are made to the plant

Diagrammatically, the accumulation of the reserve for replacement may be represented for the three methods mentioned above as shown in Fig 91

In addition to the above three systems which are in general use in the engineering industry, there are four other methods of providing for depreciation—

4 *The depreciation fund method* This system also takes into account the fact that it is always desirable to provide the capital necessary to replace a machine that is worn out, in addition to writing off its value The machine or other asset is kept at its cost value, while a fixed annual sum, called the sinking fund instalment, is debited to the Profit and Loss Account At the same time, a corresponding amount of cash is invested annually in gilt-edged securities and left to accumulate at compound interest, so that at the end of the life of the asset the total investment will correspond to the amount required for replacement

5 *The insurance policy method* This is similar to the depreciation fund method described above Instead of the annual amounts of cash being invested in gilt-edged securities, however, they are paid away as premiums on an insurance policy which secures a sum sufficient to replace the asset at the end of its life

6 *The revaluation method* In this method the assets are revalued each year and the revenue charged with the difference between the book value and the assessed value, the book value being duly written down This direct method requires the services of an expert valuer It is generally used for loose tools and other assets which cannot be conveniently treated under the above systems

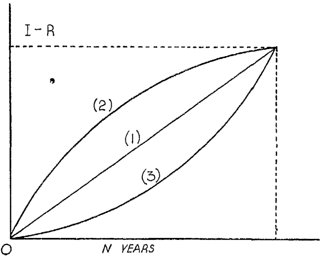


FIG 91 ACCUMULATION OF RESERVE FOR REPLACEMENT OF AN ASSET

Occasionally, expert revaluation has to be made for such purposes as evidence of value of property in appeals against rating, and with regard to income-tax allowances or claims for insurance

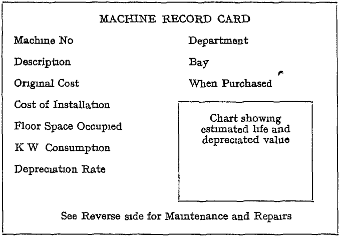
7 *The single-charge method* In this system a single amount to cover repairs, renewals and depreciation is charged against revenue

Apart from the difficulty of differentiating between repairs and renewals in some cases, the necessity arises for valuing the assets fairly frequently, and also it may be found desirable to alter the amount of the annual charge

Some undertakings, such as railway companies, take no cognizance of depreciation but pay for renewals as they arise out of funds created by transfers from revenue

RECORDS

A Machinery and Plant Register should be kept, preferably on the card-index system, having one card for each



MACHINE RECORD CARD

Machine No	Department
Description	Bay
Original Cost	When Purchased
Cost of Installation	Chart showing estimated life and depreciated value
Floor Space Occupied	
K W Consumption	
Depreciation Rate	

See Reverse side for Maintenance and Repairs

FIG 92 MACHINE RECORD CARD

machine or piece of plant The purchase price, the estimated life, the method of apportioning depreciation and the remanent value are recorded on the card, or a simple graph may indicate this information as suggested in Fig 92, though the actual graph is not shown The reverse of the card is used for particulars of maintenance and repairs including cost, so that the total expense of upkeep is available from one card

As regards the recording of depreciation in the books, it is advisable to open up ledger accounts for each asset as far as practicable, for example, separate accounts should be opened for different classes of machinery—engines, boilers, motors, shafting, general machinery and special machinery —as each class usually depreciates at a different rate These accounts interlock with the financial accounts of the firm

RATES OF DEPRECIATION

Methods of depreciation are fixed by accountants, but rates of depreciation must be determined by practical men

In fixing the appropriate rates of depreciation it is desirable to classify the assets, e g buildings, machinery, etc Tables have been drawn up showing the life in years to be expected of different types of buildings and different classes of machinery and power plant They are known as amortisation tables, and the student should consult engineers' handbooks or other sources for the depreciation usually allowed

Freehold land and buildings must be separated in the accounts The cost of any additions or partial rebuilding is debited to the asset account affected, as it is not properly chargeable against the profits of the year in which it is incurred, but is spread over a period Freehold land and buildings are usually depreciated at 2½ to 5 per cent annually In fixing the depreciation of leaseholds, it must be remembered that all expenditure on and during the lease is really payment in advance for rent, and that nothing must remain in the accounts as capital outlay in connection with the lease after its expiration If the lease has been purchased by payment in advance, revenue may be credited with interest on the investment

The depreciation of engines and boilers depends on the pressure at which they are worked, whether stationary or not, and so on The rates may vary from 10 to 20 per cent on the reducing balance, for fixtures and fittings, shafting, etc , the allowance is considerably lower, viz 5 to 7½ per cent

Loose tools are subject not only to the risks of depreciation but of loss and theft, and it is best to depreciate them by revaluation at frequent intervals

Moulds and patterns should be written off rapidly, and are frequently treated as revenue expenditure, especially if no further orders are expected

It should be noted that an income-tax rebate may be obtained under the heading of wear and tear, which does not, however, necessarily coincide with the estimates of depreciation as ordinarily defined or considered

With regard to patents it is claimed that they should be treated as if they were leases of 16 years' duration, but a valuable patent always has a residual value expressed in goodwill It is usual to accumulate a reserve rather than write off the book value of a patent

The charge for depreciation of a machine has to be recovered from the work performed on or by the machine Thus, if the number of hours running is estimated, a depreciation charge can be included in the machine-hour rate of oncost recovery

A point which sometimes arises is whether it is advantageous to invest in relatively inexpensive light machinery or more costly durable machinery If depreciation is reckoned on the straight line or diminishing-balance method, the latter type of plant appears preferable in many cases, but, if allowance is made for interest on the sum invested, the less durable type may appear the more economic proposition, and particularly if the risk of obsolescence is real

OBSOLESCENCE

A distinction must be drawn between the need for replacement of equipment by wear and tear and the same need when caused by rapid technological development In modern times the latter consideration is probably the more important A machine does not need to wear out before it must be replaced Its useful life is over when it ceases to work profitably New inventions may render it relatively inefficient although it is in good working condition and its productive value little affected

Henry Ford said that it is considered wasteful for a manufacturer to retain a machine if another appears that will do the work better or more cheaply The general theory of replacement is not, however, quite so simple as this Bearing on the decision is a complex set of circumstances, including the remanent value of the old machine, the first cost and depreciation rate of the new machine, how much more efficient it is, whether it can be kept employed all its time, and so on

The rate of obsolescence is the same whether a machine is working or standing, but, on the other hand, obsolescence usually occurs by jumps It may occur for any of the following reasons a new machine may do the work at lower cost, the product may be replaced by one for which the machine is unsuitable or improved in a way for which the machine is not adaptable, and changes may occur in taste or fashion as regards design

For general machinery the risk of obsolescence is much less than for special machinery General machinery usually finds a market, but special machines usually have only scrap value The latter machines must be depreciated rapidly, especially if the principle of the machines has been determined by the nature of the article manufactured The actual position must be frequently reviewed and compared with previous estimates

Any estimate of the economic life of a plant must therefore necessarily contain an arbitrary factor, as the extent to which practice will improve in the next few years can only be guessed at

With the present acceleration of progress and invention it is, however, safe to presume that a plant is more likely to become obsolete than wear out British machinery, for example, may suffer from longevity It has been stated that machine tools are obsolete in ten years on an average, worn out in thirty years, and written down to scrap value in fifty It all depends, of course, on the amount of use, but it seems uneconomic to run expensive machinery 44 hours a week out of the 168 possible If it is impossible to design machine tools to wear out in ten years on the lines, so to speak, of "the one-hoss shay," a suggested remedy is to run them three times as long per week Of course, maintenance would be three times as much, but capital would be turned over more quickly and the shops kept up to date

In any case, obsolete shops are injurious to the whole industry Manufacturers are, of course, aware that it would be better to have a more drastic writing-off, but the allowance on income tax for wear and tear is only 5 to 7½ per cent on the previous year's value, so that industry is frequently not able to keep its capital intact, although the law says it is

If the allowance were increased to 10 per cent, there would be less temptation to keep plant after ten years' life This question has undoubtedly been a factor in the early replacement of machinery in the U S A

Obsolescence applies to much more than machinery A whole factory, for example, may become obsolete if it is not possible to modify its lay-out or internal transport to meet modern conditions, or external transport developments may render the position of the factory obsolete

The two most important factors in industry are, however, machines and brains For the latter to be obsolete is worst of all

MAINTENANCE

A plant is a wasting asset, and maintenance is the keeping of the plant in productive condition It includes such work as cleaning, rectifying defects and effects of misuse, lubrication and prevention of wear, the repair of parts and the provision of spares

The aim of maintenance is to ensure freedom from breakdown and interruption in production By diminishing the effects of wear and tear, it extends the life of a plant (in the absence of obsolescence) and renders its operation more efficient

Maintenance constitutes a charge distinct and separate from depreciation The expense is estimated in advance and met from a Maintenance and Repairs Equalization Fund, to which equal sums are credited annually, the amount of which is determined by experience It must be remembered that the maintenance department is an overhead, so that wages and salaries must be included in the expense

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CHAPTER XI

ESTIMATING

THE successful commercial operation of a manufacturing company depends very largely upon the accuracy of estimates by which the selling price of its products are determined

An estimate is the calculation of the anticipated or probable cost of a job or project if it is undertaken Here we are concerned with estimating as a tool of management rather than with the routine of the estimating office and more particularly with the estimating work which is associated with the engineering industry It is apparent that estimating for an engineering project not only requires a sound technical knowledge of the product, an intimacy with factory methods and costs, but also a far-reaching knowledge of the market which frequently places a top limit on selling price and thus requires the estimator to influence design and production to enable a difficult market to be satisfied yet with confidence that operations will yield a consistent margin of profit

The importance of accurate estimating, apart from the danger of overestimating in a competitive market, is to guard against financial loss If underestimating goes on for a period there is, of course, the danger of eventual failure It is evident, therefore, that estimating must be based on practical experience, not only as a safeguard but because costs vary from plant to plant, and each must collect its own data

The wide variations sometimes encountered in tenders for the same job arise from lack of reliable cost data, the fact that labour cost varies from shop to shop, depending on manufacturing efficiency, and that the overheads vary considerably from firm to firm The main factors in direct costs are shop conditions and the nature of the work

Some firms may have available equipment which is most efficient for the purpose, jigs, fixtures, dies, patterns or other auxiliary equipment may be to hand, the quantities may suit the shop's capacity, the accuracy of work may be just what they are accustomed to, and so on

The important points are to ascertain if the work can be handled with existing equipment without additional expenditure, and if the manufacturing methods are the most suitable for the job in view

The most difficult work to estimate for accurately is repair work or new work, as experience may afford no data or check and a detailed estimate may be almost impossible to compile

For standard products, estimating will be extremely accurate, and for any special work which involves some modifications of standard products accurate estimating should not prove difficult

ORGANIZATION OF ESTIMATING DEPARTMENT

The estimating department should be divided into sections, each dealing with one product of the firm's manufacture or with the products of one manufacturing department The advantage of specialization may be seen from examination of the procedure on receipt of an inquiry The specifications must be examined, and any abnormal conditions, guarantee required, etc , must be noted Drawings must be obtained, and quantities and weights determined with due regard for allowances and scrap Parts to be bought must be decided upon, and their prices obtained The work to be undertaken by the firm must be analysed with regard to the methods of manufacture involved, including a decision as to whether any new tackle, jigs or fixtures are required The operation times must be worked out, and rates fixed so that the labour costs can be ascertained The overheads must be allocated scientifically and not guessed If any tests are specified the costs of carrying them out must be included The estimate must be checked and compared with any established costs available for similar previous work

It is obvious that if the work is to be done with expedition it involves collecting and filing data, classifying and tabulating them ready for use, the employment of graphical methods, and, whilst help may be obtained from department heads, sufficient technical and practical knowledge to know that the data are reliable and under what conditions they apply

ESTIMATING STAFF

Apart from an ability to co-operate with the designing and works staff, the purchasing department, the cost office, and the time-study and rate-fixing department, it is desirable that the estimating staff should have shop experience, as accurate estimating without experience is almost inconceivable A man in the estimating department should have a good general knowledge of the plant and the capacity of the machines, also a knowledge of the design he is estimating on and to judge if it is properly adapted to production Otherwise he cannot analyse the shop problems involved nor forecast variables in costs, nor determine what proportion of the charge for drawings, patterns, jigs, tools, etc , should be included in the estimate

He must be systematic in his work, have information readily available, and be capable of using rapid methods, as spot estimates may be on occasion a vital necessity to the sales department Standardization will assist the estimator's work He must, of course, be conversant with the inter-trading facilities possessed by his firm and the discounts allowed to them by their connections

ESTIMATE OF MATERIALS

For any given inquiry a schedule of items is made and the price of each obtained, together with the time required to receive Estimates are, of course, made out ahead of the work being put in hand, in fact, contracts may be offered for competition long before they are placed Consequently, the estimator must be conversant with price trends and be able to forecast the probable market prices in order to make due allowances for price fluctuations in the tender To this end he may make his own price charts or abstract from the technical press, for example from the *Iron and Coal Trades Review* for iron and steel If prices are likely to alter, he may introduce a clause that the price is subject to revision after the lapse of a certain time, or he may state the basis price of the raw material and how any alteration will affect the amount of the tender

An important part of the estimator's work is the taking out of quantities or estimating weights of materials Drawings may only show the finished dimensions, whilst the estimate must take into account the rough sizes and weights A practical knowledge of allowances and how they vary with size of product is essential for this work Calculating the weight of castings and forgings may present some complicated problems, whilst for an engineering estimate such diverse products as forgings, castings, girder work, plate work, brick and timber work may be included The estimator must have a sound knowledge of common metals, their density, their price and their scrap value To consider only pig-iron, wrought iron and steel, alloy steel, copper, bronzes, and brasses, aluminium and its alloys and bearing metals indicates that this is no light task The estimator must also be conversant with British Engineering Standards

He need not, of course, burden his mind with the enormous amount of detail involved in the above, but he must have all the data immediately accessible in his data books and files

In estimating for accessories the estimator will make use of the firm's collection of engineering catalogues It may be advantageous, although the firm can manufacture components or accessories, to obtain quotations from outside, as it will be a check on the firm's own estimates.

ESTIMATE OF LABOUR COST

The estimate of labour cost may be made by reference either to similar work or to the foreman, or by calculation

It is more difficult than to estimate materials cost, especially if estimating is regarded in its proper light, that is, not carried out by guess work, but by means of careful approximations, if not ascertained facts

The planning department usually fixes the materials, production methods and sequence of processes, and the jigs, tools, and fixtures required as the type of plant used will affect the output and cost, but the estimator may on occasion have to do some of this work himself As was seen in Chapter VII, rate fixing should be based on time study The rate fixer has the basic information and sometimes has worked out rules for the times required by various machines, but estimating is less a matter of rule than of judgment, reasoning, and knowledge based on past experience The estimator must understand the governing conditions in a shop, consulting where necessary the superintendent or foreman, as there is not as a rule enough co-operation between the production engineers and the estimator It is no use, for example, estimating in the ordinary way if the shop conditions are such that overtime or night-work is necessary to undertake the stipulated delivery The estimator must know the capacity of the machines as well as their performance

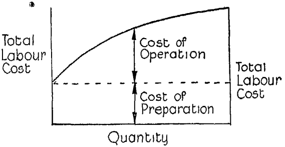

FIG 93 DIAGRAM ILLUSTRATING THE EFFECT OF PRODUCTION QUANTITY ON LABOUR COST

The estimator will require to appreciate the difference between machining times and floor-to-floor times the allowances for defective materials, the allowances for defective labour, and such items as the cost of marking off, the cost of set-up, the cost of tools, the cost of inspection, the effect of multiple tooling, and so on The effect of long runs on labour cost must be appreciated It is clearly brought out in Fig 93 The estimator must also know if the firm is manufacturing under licence so as to load on, if necessary, the royalty charge to the cost of production

Let us suppose that besides being able to read specifications and drawings, having a knowledge of mensuration and a practical knowledge of shop conditions, the estimator has to do rate fixing for himself

It will be useful for him to fix standard times for both machine work and hand operations, but this is possible only if he has experience and a knowledge of the capabilities of machines and tools and the character of the work Suggestions may be given for formulae to use with certain classes of work, but consideration of operating time is insufficient by itself and non-operating time must be taken into account, such as the supply of drawings, instructions, jigs, tools and gauges, the time for set-up, adjusting machine and tools, removal of work, and so on

Provided tools are standardized, formulae may be developed for cutting speeds in rough turning and finishing, milling, drilling, screw-cutting, planing, shaping, slotting, etc , and so the time required for various jobs can be determined

Although short cuts usually fall under suspicion, formulae are frequently of great time-saving value and help to prevent the estimating department becoming a bottle-neck from the point of view of the sales office It is, of course, assumed that before using the formulae for new work they have been checked up against the recorded times of operations within their range

The engineering student should look up these formulae in his notes or from machining handbooks, but the following are given as simple examples—

Drilling

$$\text{Time in minutes} = \frac{\text{Depth in in}}{\text{Revs per min} \times \text{feed per min}}$$

Approx time to drill 1 in deep in metal (secs)

Metal	Periph Speed f m	Diam of Drill				R P M
		⅛″	¼″	½″	1″	
Aluminium	400	7	5	4	3	1500
Brass	200	10	7	6	8	1500 1500, 1500 764
Mild Steel	90	14	10	13	16	1500, 1375, 688, 344
Cast Iron	50	10	11	16	22	1500, 764, 382, 191

The allowances in drilling include time for lifting the component, loading, manipulating, raising and lowering gauging

Reamering

Reamers run at half the speed and twice the feed, hence allow about the same time as drilling

Tapping

$$\text{Time tap is in the hole} = \frac{\frac{3}{2} \times \left(L + \frac{D}{2}\right) \times 60N}{\text{R P M}}$$

where D = diam of tap
L = depth of full thread
N = No of T P I

and assuming a 2 1 ratio for quick return

Handling Time	Tap	¼ in	½ in	1 in	1½ in
	Secs	5	8	12	15

Tapping times per tap per hole Whit , B S F and gas

Material	*Seconds*	*Depth*
Aluminium	10D + 2	2D
Brass	16D + 2	3/2D
C I	24D + 2	3/2D
M S	32D + 2	5/4D
Tough Steel	48D	

These times include manipulation and gauging, not loading

Planing, Shaping, Slotting

$$\text{Time in minutes} = \frac{\text{W N C}}{\text{S}}$$

where W = width in in
N = No of feeds per min
C = No of cuts
S = No of cycles per min

Example Length of stroke 6 ft
Cutting speed 30 ft p m Return speed 90 ft p m
Cutting stroke 12 sec Return stroke 4 sec
Reversal time factor 7 sec
Time per cycle 23 sec

Cutting speeds for shaping, ft p m

C I	M S	Brass	Ali
35	60	80	80

Time for shaping a surface L × B sq in $= \dfrac{(L+2)\ (B+1)}{K}$

where K =

Material	Roughing Cut	Finishing Cut
C I	8	16
M S	10	16
Brass	20	30

For planing the effective speed is usually 30 ft per min

Time in min for planing L × B sq in $= \dfrac{(L \times 10)\ (B+2)}{360F}$

where F = feed per stroke in in

Loading Time = 3(L in ft × B in feet) + 12 $\sqrt{\text{weight in cwt}}$

Milling

$$\text{Cutting time} = \frac{\text{Total travel during cut}}{\text{feet per min}} \times 60 \text{ sec}$$

$$T = \frac{L + A + O}{F}$$

where L = length of cut in in
A = approach of cutter
O = overtravel of cutter
F = feed in in

Material	*Feed* (F)
Ali	24
Brass	16
C I	8
M S	6

H P at cutting tool can be calculated thus—

$$\frac{\text{r p m} \times \text{diam of lineshaft pulley} \times \text{width of belt}}{3600}$$

Approx Rule 1¼ H P removes 1 c in of M S per min

Approx sawing time for M S on milling machines (sec)

Size	Loading	Manipulating	Cutting
4 in	90	30	140
3 in	60	30	90
2 in	30	20	40
1 in	20	15	20

Turning

Cutting time to turn $= \frac{n}{\text{r p m}}$ where n = number of cuts per in

$$\text{Cutting for length } L = L \times \frac{n}{\text{r p m}}$$

$$= L \times \frac{\pi D}{12} \times \frac{n}{\text{cutting speed}}$$

assuming 50 cuts per min and cutting speed of 90 ft per sec

$$\text{Time} = \frac{L \times D}{7}$$

Approximate setting up times	small lathe	20 min
	12 in lathe	30 min
	heavy lathe	40 min

Approximate Chucking Times	Weight of Casting	
	2 lb	60 lb
Self-centering jaws	½ min	3 min
Independent jaws	1 min	5 min

Steadies Allow 10 min to set, 3 min to adjust

Gauging times 5 to 30 sec

Boring

Feeds and speeds approximately the same as for turning Allow one more cut

Screw Cutting

Number of cuts or passes $\frac{64}{\text{T P I}}$ (external) or $\frac{80}{\text{T P I}}$ internal

Time for each pass $\frac{L \times \text{T P I} \times 60}{\text{r p m}}$ ft p m = 30 to 100

Turret and Autos

Set-up times	min
Changing collets and adjusting to grip bar	4
Grinding tool	5 to 10
Setting screwing die	6
Grinding and setting drills	4
Grinding and setting parting tool	5"

For autos

Cycle time = floor-to-floor time plus bar feeding allowance
Operation time = cycle time + fatigue and tool allowance
Basic time = operation time + contingency
Piecework time = basic time + 25 per cent — No of machines
P w price = p w time × basic rate

Grinding

$$\text{Grinding Time} = \frac{\text{Grinding allowance} + \text{compensation}}{\text{Number of passes per min} \times \text{feed per pass}}$$

Approx grinding allowance	Diam	1 in	2 in	4 in
		010	015	020

Compensation varies between 10 to 60 per cent

Feed per pass, 001 to 003 in

$$\text{Traverse} = L - W + 1$$

Where L = length of work
W = width of wheel

$$\text{Number of passes per minute} = \frac{\text{Total travel}}{\text{Traverse}} = \frac{\text{r p m} \times W \times \frac{1}{2}}{L - W + 1}$$

If D = diam of work,

work speed = external grinding, $\frac{160}{D}$ internal $\frac{240}{D}$

$$\text{Grinding Time} = \frac{(G\,A + C)\,(L - W + \frac{1}{2})}{\text{r p m} \times W \times \frac{1}{2} \times \text{feed}} = \frac{(G\,A + C)\,(L - W + \frac{1}{2})D}{180W \times \text{feed}}$$

Approx times	Diam	½ in	1 in	2 in
	Time	6 to 9	7 to 10	9 to 13 min

Allowances wheel dressing, preparation and setting up gauging, loading

Welding

Approx rate of welding mild steel (butt welds)

	Oxyacetylene	*Electric*	
⅛	8 min per ft		30 per cent fatigue allowance
¼		4 min per ft	
½		7 " "	

Oxyacetylene cutting

¼ in	0 9 min per ft run	25 per cent fatigue' allowance
1 in	1 25	
4 in	3 0	

Filing

Per sq in minutes

	M S	*C I*	*Brass*
Rough	0 5	0 25	0 16
Finish	1 0	0 50	0 33
Burrs	1½ min per linear ft		

As an exercise the student is also recommended to make his own list of cutting speeds and feeds for the various machining operations on ordinary engineering materials, specifying the tool steel used

Standard times for hand operations are more difficult than for machine operations, but if the materials are standardized they can be attempted for filing, scraping, polishing, tapping, riveting, caulking, welding, and so on, in view of their value in estimating

The estimator will have to understand the economics of grinding because, whilst greater accuracy and uniformity of finish can be obtained by grinding, problems may arise as to whether it is more economical to machine or to grind when accuracy, finish, labour cost, and machine charges are all taken into account

The following factors will affect the decision the amount of material to be removed, if the work can be done simultaneously with another operation, and if roughing and finishing cuts can be taken successively with the same tool or wheel

To facilitate the work of the estimator, machine reference data must be kept up to date and accessible, and if machine cards are prepared as recommended in Chapter X, but including the setting-up and adjusting times together with time-study information and other reliable data, they will prove useful in the present connection as well as to the production engineers

Information on the following operations may be kept in loose-leaf books or might with advantage be diagrammatized sawing, turning, drilling, boring, reamering, shearing, milling, planing, shaping and slotting, gear cutting, grinding, centreless grinding and polishing, with times for setting-up and removing work, heat treatment, welding, oxygen-flame cutting, die-casting times, handwork, erection, and so on

The estimator has to convert operation times into money values, so that he has to know the rates of the various classes of labour, which he may well keep tabulated He must be conversant with the wage system extant, whether individual, payment by results or collective bonus, and the effect it has on the labour cost Besides tabulating the rates per hour, he may find it advantageous to collect data on the cost of removing metal per lb or treating it per square foot, as for example in the operation of grinding

ESTIMATE OF OVERHEADS

Overhead charges are the most difficult portion of an estimate, and it is mainly due to variations in these charges that differences in prices quoted by competing firms arise The oncost charges will be decided by the cost accountant of the firm—in fact, it is difficult to see who else could advise on establishment charges—but the estimator must be conversant with what oncosts are, how they arise, how they decrease with increasing production, and how they should be allocated

He must know that overheads consist of factory expenses, selling expenses and general or administrative expenses, though it will be the first-named with which he is more directly concerned The estimator must appreciate that a general overhead on the whole of a factory's production is to be condemned, and if it is impossible to allocate overheads by products they should at least be departmentalized As overheads are such a vital factor in competitive tendering, the estimator must understand the importance of ascertaining under whose control the overhead charges fall, so that responsibility can be fixed and efficiency of management checked In choosing between the various methods of allocating workshop expenses, the estimator must try to determine what is the factor most nearly correlated to these expenses, for example, in choosing between the machine-hour and the man-hour methods, is the machine or the operator the controlling factor? He must also appreciate why different methods of allocation are used for different shops, such as the pattern shop, the foundry, the smithy or forge, and the machine shop

As a guide, the following figures expressed as a percentage oncost on direct wages may be taken machine shop, 150, fitting shop, 100, smith's shop, 100, and pattern shop, 75

ESTIMATES

The headings under which an estimate is drawn up vary with the class of production, but the following may be suggested—

Description	Quantity	Material			Operations	Wages
		Finished Weight	Gross Weight	Cost		

Workshop Expenses	Establishment Charges	Packing Charge	Delivery Charge	Total Cost	Profit	Price

Each firm will find from experience the simplest form of estimate sheet to meet their own requirements, but it will be seen that the chief points are covered by the following—

ESTIMATE FORM

Inquiry No	Customer	Date
Description		Number off

Materials	
Parts bought out	
Total Materials Total Labour (*see back*) Total O/H (*see back*)	Delivery Promise
Contingency Allowance Profit	
Packing Carriage Extras	
Minimum Selling Price	

A somewhat more detailed form of estimate, together with a formal quotation based on this estimate, is given on pages 385 and 386

Packing and shipping will receive the estimator's attention in order to secure the most economic charge There may, for example, be alternative methods of packing and there is no need to go to more expense than necessary, such as packing as if for export when the goods have to be delivered in this country Certain orders may, however, call for special packing, and the estimator must allow for this His records may yield the cost of freight, but it is probable that he will consult the traffic department as a good deal of specialized knowledge is involved in determining the cheapest transport method and route, e g road *v* rail Road transport is usually cheaper for loads below 4 tons, but not for small consignments Moreover, the traffic manager may be able to make the consignment part of a

ESTIMATE No 1111

Date Customer

Quantity Description *H R Steel Valves*

Drawing No

				Total	Each	Total Each
Material	2,500 ft of Centreless ground bar H R steel bars in multiples of 8 in (Allow 5% extra)			£41/10	2d	2d
Operations		Labour	Overhead			
Cutting to length					¼d	
Electrically upsetting					1d	
Forging the head					¾d	
Stelliting the seats					1d	
Heat treatment		Furnace-hours			½d	
Grinding head					1d	
Grease						
Total					4½d	
Contingencies (10 per cent)					½d	
Profit (20 per cent)					1d	8d
Tools	Tool steel die to Drawing 222			£31	1½d	9½d
Packing				£3	¼d	
Carriage				£2		
Total						9¾d
Selling Price						10d

Delivery 14 days Estimated by

FIG 94

The A B C Company, Ltd
Valve Works,
London

QUOTATION 1111

Messrs X Y Z, *Ltd*
London, *S W* 1

11*th November*, 19

Dear Sirs,

In reply to your esteemed inquiry of the reference we have pleasure in offering to supply you with—

		Price
5,000	H R Steel Valves, in accordance with your drawing No 1234 stellited on the seats and heat-treated to conform with Specification No 4321 @	10d each net

Delivery for your Works, 14 days from receipt of order

Terms Net cash within 30 days of the end of the month of dispatch

This offer is open for acceptance within 14 *days*

Conditions

Every effort will be made to secure sound material and good workmanship, and we will replace free of cost and under the same conditions of delivery as the original contract, any material which proves faulty within six months of delivery or setting to work Our responsibility shall, however, be limited to the above and shall not include consequential damages such as loss due to stoppage of machinery

The time of delivery is named subject to the non-occurrence of accidents, strikes of workmen, trades disputes or other causes beyond our control

Yours faithfully,

Fig 95

car-load and so obtain a cheaper freight rate, or advise on the most economic size and weight of package

The estimator will, of course, have observed whether the delivery is F O R , F O B , C & F or C I F

Note—

F O R Free on rail (at maker's works)

F O B includes carriage to port, porterage and cartage at port, dock and town dues

C & F. includes F O B charges plus freight, shipping agent's commission, and bills of lading

C I F includes C & F charges plus insurance

For export charges, the services of a shipping agent should be used, as it is a specialized work The packing must, of course, be substantial to prevent damage at sea Care must be taken with marks and records so that consignments may be identified and traced

ESTIMATING PROCEDURE

Let us now recapitulate the procedure from the receipt of an inquiry The sales office acknowledges the invitation to quote and sends it to the technical or planning department with the specification, or to make out the requisite drawings Estimating may thus be considered to have three stages the fixing of design, accuracy, and finish, the work of the estimate department proper, and obtaining a reliable delivery promise from the progress department in view of the existent load on the shop The planning department (of which the drawing office is assumed to be a section) will set down the requirements and specifications, and types and quantities of materials, look out or make out the drawings, and lay down the methods and sequence of operations, machines to be used, allowed times and rates of labour

The job specific to the estimating department is—

(1) To determine the weight of all materials, including all allowances

(2) To determine the cost of materials either at market price or a forecast price, or at 'a' basis price with a statement of allowances for variations

(3) To determine the price of outside purchases and how soon they can be obtained

(4) To determine the labour cost of each operation from performance times and wage rates, including manufacturing and assembly, also testing and erecting if necessary

(5) To determine the cost of any special tools or auxiliary equipment necessary and how this cost is to be spread

(6) To make contingency allowances based on experience

(7) To determine the time of delivery in collaboration with the progress department, if a definite delivery date must be guaranteed, to ascertain if overtime or night work is necessary and make corresponding adjustments

(8) To ascertain the factory oncost in collaboration with the cost office

(9) To ascertain the general overhead from the accountant

(10) To check by comparison with similar work

(11) To examine any guarantees, conditions and special points, e g with regard to delivery, and see that they can be met

(12) To determine packing charges

(13) To determine delivery charges and cost of insurance in transit if necessary

(14) To add the standard profit and submit the estimate to the directors for their decision

(15) To hand the estimate to the sales department for dispatch of the quotation or tender

With reference to point (6), the contingency allowance on commercial work is less than on Government or similar contracts

Under point (11), the question of assembly or erection on site may arise, in which case an estimate will have to be made of the labour cost, oncost and fares and sustenance allowances

The terms suggested in the inquiry will have to be carefully examined to see if there is anything unusual, for example, in regard to time of completion, responsibility for delays and stoppages, responsibility for consequential loss and damages, and so on

As regards point (14), the percentage added for profit is very frequently a matter of policy The price quoted largely depends on trade practice If the trade is of a monopoly character, the price may have no relation to cost, but in ordinary competitive industries except for cases of differential, discriminatory, and emergency prices, it will, of course, be conditioned by the cost of production The percentage profit added will usually, however, depend on the quantity of goods ordered, but even further concessions may be made to certain customers In tendering for foreign work the profit added is usually higher to offset inconveniences of irregularity in currencies and other uncertainties In general, it may be said that the larger the contract offered, the larger will be the radius over which tenders are received and the greater the tendency to cut profit margins If complete specifications are supplied the tendency is also to cut prices, but if a general specification is issued firms generally specialize in offering the best design and specification and let the price take care of itself

If a tender has to be itemized, a small profit is put on parts of which many are required and a large profit on parts of which only a few are wanted

Whilst general designs of plant may be fairly standardized, makers often have to quote for special sizes and types, and much time and cost in estimating may be saved if study has evolved useful formulae for estimating purposes, e g in the case of engines cost per brake horse-power, weight per brake horse-power and cost per ton Of course, such cost estimates cannot claim close accuracy, but the manufacturer is always faced with the problem of deciding the degree of accuracy he requires in view of the fact that every quotation does not become an order For a high ratio of quotations to orders, estimating may become a bottle-neck Estimating formulae then become very useful, and in the event of an order the planning department is given a free hand to achieve all possible economies in methods of production

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